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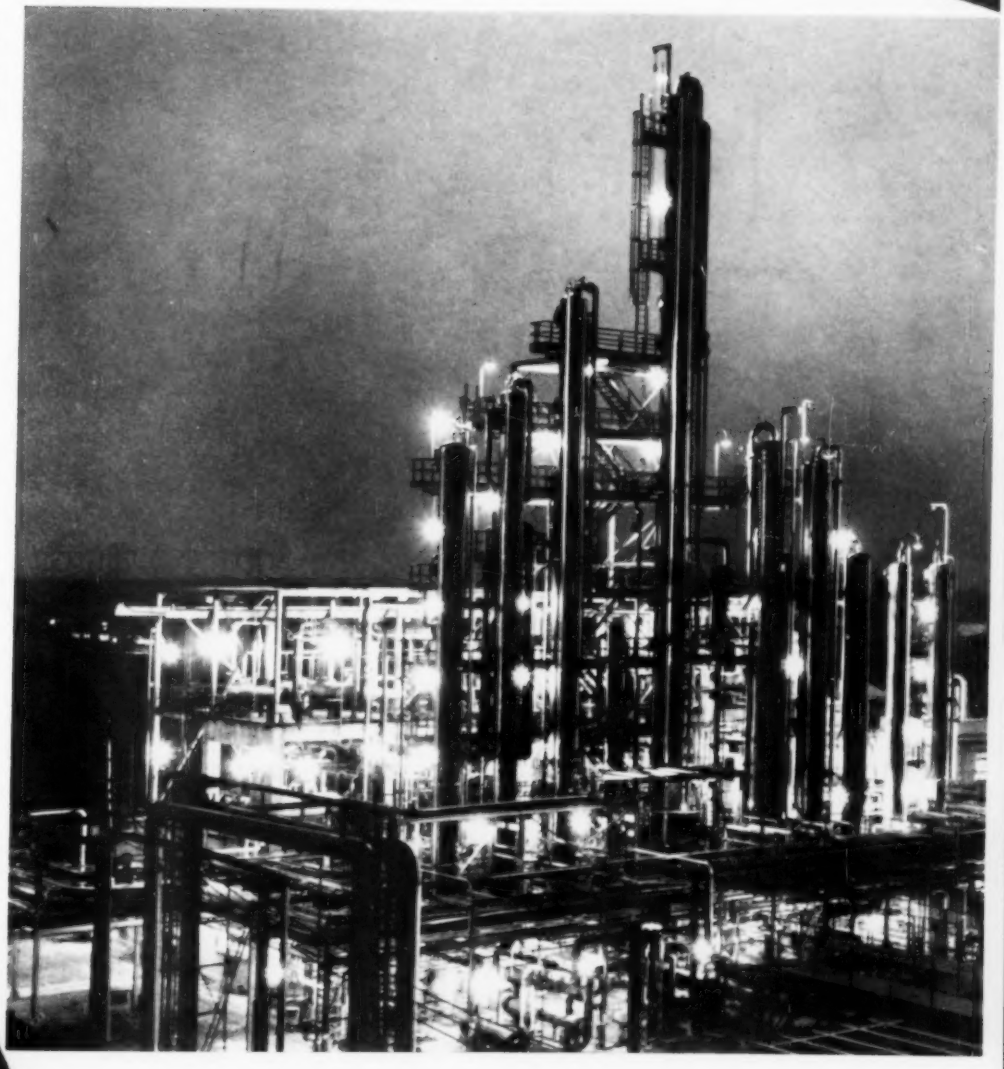

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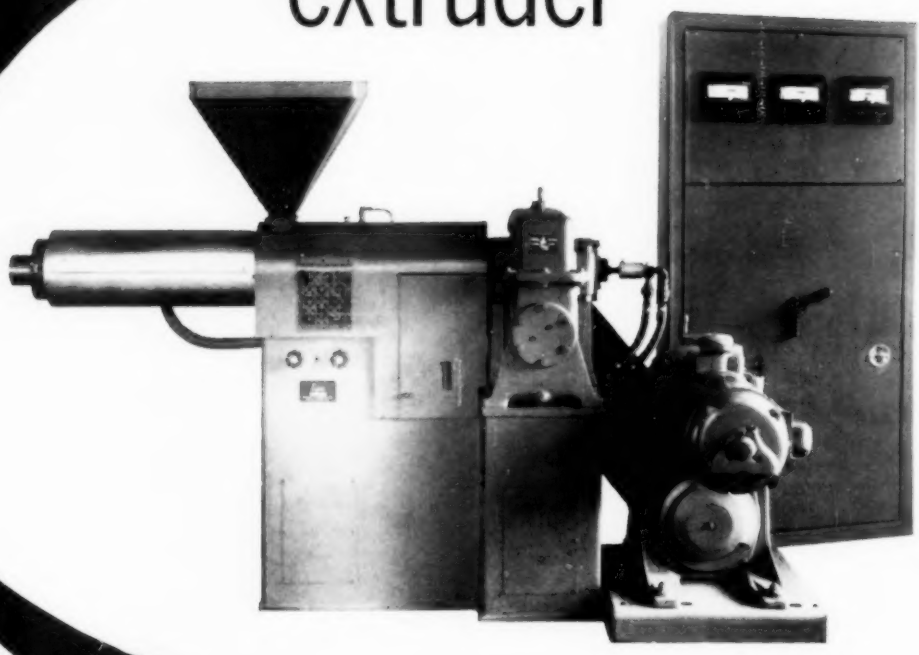

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All material for publication in the SPE Journal, such as manuscripts, abstracts, news releases, orders for reprints, magazines for abstracting and books for review should be directed to the Editorial Offices; Dr. Jesse H. Day, Ohio University, Athens, Ohio.

Jesse H. Day

INDEX

ARTICLES

Theory of the Changes in Physical Characteristics of Plastics caused by Radiation—J. W. Ryan 11
The Crazing of Polystyrene—E. E. Ziegler 12
The Extrusion of Film and Sheeting—George Kovach 24
Why More Plastics?—Archibald Renfrew 22
Polyester Resins and Their Industrial Applications—I. E. Muskat 28

FEATURES

Across the Editor's Desk 4
Book Reviews 5
Industry Notes 6
Your National Office 8
The Injection Molderscope 30
Plastics Around the World 31
News of the Sections 35

ADVERTISERS

A. Bamberger Corp. 45
Art Making Specialists, Inc. 45
Bakelite Co., a Div. of Union Carbide and Carbon Corp. 14-15
Barrier-Pribble and Co., Inc. 41
Caco, Inc. 6
Durez Plastics and Chemicals, Inc. 4
Frank W. Egan and Co. 2
Gering Products, Inc. 5
Hercules Powder Co. 48
Hydraulic Press Mfg. Co. 10
Industrial Mfg. Corp. 39
Injection Molder's Supply Co. 4, 39
Manco Products, Inc. 35
Monsanto Chemical Co. 9
Shell Chemical Corp. 7
Sterling, Inc. 6
Watson-Stillman Co. 47
Classified Ads 46

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Across the Editor's Desk

Hugo Becker

E. Davey-Turner

● We always felt a little sympathetic toward a certain newspaper editor who once printed a reference to "battle-scared" veterans. Next issue he humbly apologized for the misprint, saying of course what he **meant** was "bottle-scarred" veterans. Now we know how he felt, since Mr. Hugo Becker of Crucible Steel Co. of America notes that not once, but **twice**, we switched his photograph with that of Mr. Davey-Turner! Here are the photos with correct captions at last!

We take this opportunity to note that Mr. Becker's excellent article on Tool Steels for Plastics Molds is scheduled for early publication in the SPE Journal.

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Book Reviews

ORGANIC COATING TECHNOLOGY, Vol. 1, by Henry Fleming Payne. John Wiley and Sons, Inc., 440 Fifth Ave., New York 16, New York. Publication date Feb. 3, 1954. 674 pages, ten dollars.

Organic coatings technology is the technology of large molecules, synthetic or natural, and their plasticizers and solvents. Hence a book like this one, while indispensable to the paint and varnish chemist, is also of immediate interest to any plastics chemist, and to anyone in the plastics industry.

Your reviewer has read a great many books on plastics and coatings, despite which he was moved to a loud cheer now and then while reading this book. But to take things one at a time.

The book is lucidly written and beautifully organized —a virtue not always apparent in all books — and covers the field in a wealth of interesting and practical detail. Chapter 1 deals with the fundamentals of film formation, discussing the setting-up of film from the viewpoint of chemical structures and reactions, and the use and effects of solvents, pigments, and so on. Chapter two deals with vegetable and marine oils for organic coatings; and while this is a basic must for the varnish chemist, it is a fascinating holiday for the plastics chemist, since the two fields are at bottom quite close and yet the plastics man seldom gets much opportunity to cross over.

Succeeding chapters describe varnish resins, varnishes, driers, and volatile solvents. The rest of the book could be used as the basis for a course in plastics, and indeed is more complete than many plastics books — with the exception that polymers are considered strictly for organic coatings.

Chapter headings are: Alkyd Resins; Urea- and Melamine-Formaldehyde Resins; Rubber Resins; Plasticizers; Cellulosic Polymers; Vinyl Resins; Acrylic Ester Resins; Silicone Resins; and Test Methods. Chemistry and preparation of the polymers are discussed, costs, uses, properties and formulations.

The author is technical editor of the American Cyanamid Company, and adjunct professor at the Polytechnic Institute of Brooklyn, and has had 30 years of experience in the coatings field. While leading a double life might be upsetting to some, in this case it has led the author to a happy marriage between theory and practice.

Who should own this book? Well, first off, any student or new employee in the varnish industry will use it as a textbook; an old-timer as a compendium and ready-reference; the plastics chemist and the manufacturer of polymers; the professor in either field; and lastly, but not least, the plastics man in any branch of the industry who is interested in extending his knowledge of plastics materials into a related field.

You have doubtless noted that your reviewer sometimes has fun finding misprints; they may exist in this book, but I didn't find them.

The references cited liberally at the end of each chapter refer to material as late as 1953. **J. H. D.**

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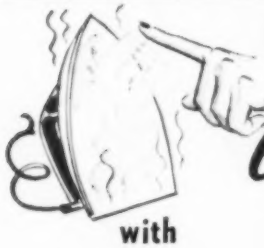

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Central Ohio	33	1	0	0	5
Chicago	315	21	6	1	9
Cleveland-Akron	148	17	6	4	18
Connecticut	86	7	1	2	11
Detroit	173	13	4	5	12
Eastern New England	132	5	4	1	8
Golden Gate	32	5	3	1	28
Miami Valley	102	2	0	1	9
Milwaukee*	1	—	8	0	—
Newark	321	31	6	0	12
New York	248	22	12	14	19
Northern Indiana	21	1	2	2	24
Northwest Pennsylvania	75	8	0	1	12
Ontario	43	23	31	0	120
Philadelphia	174	9	12	7	16
Pittsburgh	6	8	0	2	—
Quebec	25	16	8	2	104
Rhode Island & S. E. Mass.	68	4	3	0	10
Rochester	65	10	2	1	8
St. Louis	71	13	1	2	22
Southeastern Ohio	36	4	0	0	11
Southern California	96	15	3	2	21
Southern Section*	3	—	9	24	—
South Texas	32	6	1	2	29
Toledo	59	0	1	0	3
Upper Midwest	54	5	3	0	17
Western New England	135	15	7	7	21
Non-Section	33	0	0	6	—
TOTALS	2704	267	135	90	18

*New Sections!

6th Conference, A.I.E.E. on Electrical Problems in Plastics Industries

The American Institute of Electrical Engineers Sub-Committee of the General Industry Applications Committee has planned the 6th Annual Rubber and Plastics Technical Conference to be held Monday and Tuesday April 5th and 6th, 1954, at the Mayflower Hotel, Akron, Ohio.

Preliminary arrangements have been made for an inspection trip through the Firestone Tire and Rubber Company, Plant Two, Akron, Ohio.

A banquet will be held in the Mayflower Hotel Ballroom, Monday night, April 5, 1954, at 6:30 P.M. Dr. S. M. Cadwell, Director of Research and Development Departments, U. S. Rubber Company will speak on the subject "The Future of Synthetic Rubber."

A.I.Ch.E. Meets In May

The spring National meeting of the American Institute of Chemical Engineers will be held in Springfield, Mass., at the Kimball Hotel on May 16-19. Included in the program will be a forum on "Training of Technical Men in Industry," Symposia on "Polymeric Materials of Construction," "Cost Control" and "Process Design," and general technical sessions.

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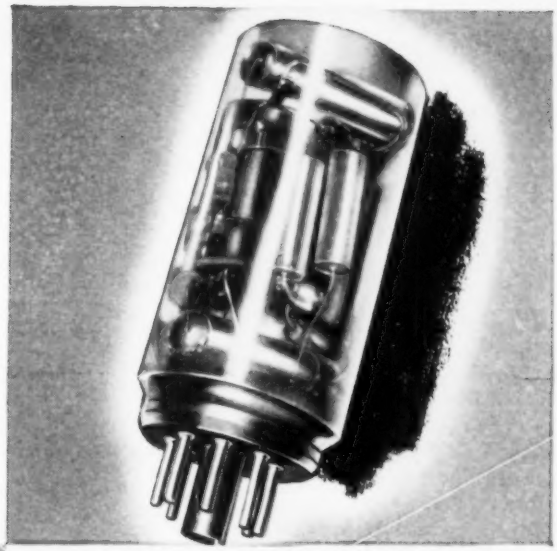

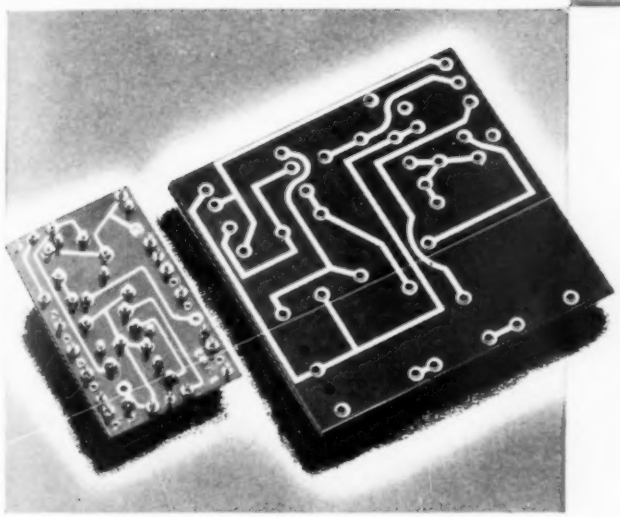

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Conversation on a Plane

While traveling on planes or trains I frequently get into conversations with other travelers — as you do too, no doubt. For me one might go something like this:

Traveler: What kind of work are you in?

Executive Secretary: I work for the Society of Plastics Engineers.

Traveler: Plastics — that sure is a growing industry. What sort of product does your company sell?

Executive Secretary: Service — to the individuals in the plastics industry. You see, the Society is an organization of individuals, holding responsible positions, in all branches of the plastics industry. They get together socially in local section meetings . . .

Traveler: Oh, like a fraternity.

Executive Secretary: Well, a business fraternity yes, but brotherhood is only part of it. SPE members meet to increase their understanding of the plastics industry by formal discussions and films on technical matters of current interest and practical value. The conditions are also good for cooperation being developed among the individuals in various phases of the industry who **must** join efforts if many technological difficulties facing them, their companies, or even the entire industry are to be overcome.

Then too, informally, members and guests meet the people in their locale whom they depend on for materials, equipment, or orders. **Friendly contacts improve business relations.**

Traveler: You say you work for the Society. Do you mean you give talks to these sections?

Executive Secretary: Yes, talking before the various sections is part of my job — mostly about Society activities. Let me explain it this way. **Each SPE member you might say belongs to two organizations in one:** his local section and the "National Organization"; something like being a citizen of the State of Ohio and of the United States at the same time. The activities of the sections are expanded to a national and international area of operation by the "National Organization." Our technical magazine, the SPE JOURNAL, is distributed internationally. The "National Organization" also conducts a technical conference annually which is an enlarged local section meeting — this year it was on an international scale too. And there is a National Technical Advisory and Service Committee to recommend solutions for individuals' technical problems. **In these ways the "National Organization" directly serves each member.** The "National" serves the sections by coordinating their work, processing membership applications and routine work. It serves the industry not only by serving the individuals in it but also directly through its work in professional activities and education. So you see, service is the work of the Society on all levels.

My job is generally concerned with the management involved in these activities of the Society.

Traveler: But who owns the Society?

Executive Secretary: It is like any corporation. The individual members are the stockholders. They themselves elect a National Board of Directors to govern. **Since it is their own independent organization the individual SPE members "own" and control their entire Society!**

P. L. Underwood

Executive Secretary

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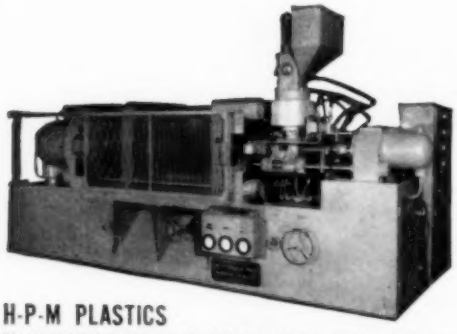

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Theory of THE CHANGES IN PHYSICAL CHARACTERISTICS OF PLASTICS CAUSED BY RADIATION

J. W. RYAN
General Electric Company
Schenectady, New York

FOR A NUMBER OF YEARS there has been a feeling in the General Electric Company that there is a very substantial place in the field of plastics engineering for treating polymerized or polymerizable materials with high energy radiation.

There are three types of radiation sources which are ordinarily used to bring about changes in the properties of plastics. These sources are alpha, beta, and gamma ray generators.

The limitation in the use of alpha radiation is the very short penetrating path that the helium ions have when passing into dense materials. This means that only surface effects would be noted upon exposure of a solid material to these rays. Commercial applications are limited because alpha ray sources are usually made from the salts of heavy metals and do not have high intensities. They present a serious health-physics problem because of the possibility of ingestion.

Beta ray sources can be obtained from electron accelerators such as the General Electric resonant high voltage cathode ray apparatus, Van de Graaf generators, Betatrons and Synchrotrons or from fission product isotopes such as strontium 90.[3]

A discussion of the characteristics of these machines is beyond the scope of this paper. However, experimental machines are in operation in some of our leading industrial concerns. These are being used primarily in fields concerned with the sterilization and storage of foods and pharmaceuticals, and in the field of chemistry to produce useful chemical changes in materials.

Beta particles are electrons and have a greater penetrating power than alpha particles because of their mass and unit negative charge. It is possible through proper techniques to obtain uniform exposure of relatively thin (3-5 mil) sheets of plastic materials by use of this type of radiation.[3]

RADIATION SOURCES ARE EXPENSIVE

The sources which are associated with in-pile irradiation are expensive at the present time, but this should not preclude their use in the future. (In-pile irradiations are obtained by exposing the materials to treatment in an atomic reactor.) These reactors emit alpha, beta, and gamma radiations as well as neutrons. The neutrons present a problem as most inorganic impurities will capture thermal neutrons and become radioactive. Among the particular elements which would have to be controlled very carefully would be iron, cobalt, zirconium, and strontium. Parts per million of impurities of this type could produce enough artificial radioactivity to prevent their use in home or laboratory unless special precautions were employed.

Gamma and X-rays, because of their electromagnetic nature, are the most penetrating of all the types of radiations and, as such, afford a means of obtaining exposures of thick sections of plastic materials.[4]

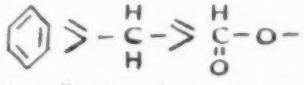
The principal mechanisms of radiation absorption by gamma and X-rays are the Compton, pair-production and photoelectric effects. The particular effects observed depend to a large extent on the energy of the photon reacting with the electron field of the atom concerned. In the study of organic compounds it is found that these absorption processes result in the formation of free radicals and ions. These free radicals form low molecular weight gases, cross linkages, rupture polymer chains, and produce double bonds. The free radicals are therefore responsible for the process of polymerization, depolymerization, decarboxylation, oxidation and reduction which have been observed to occur.

In addition to these processes I suggest[4] that there exists a "Functionality Series" such that the highest functional group tends to transmit energy received from the interaction with a photon to a lesser transmitting group where it selectively decomposes.

This term "Functionality" means any one of the building units of the polymer in question. For example nylon could be considered as being composed of methylene, carbonyl and secondary amide functional groups.

Evidence for this hypothesis can be obtained from a study of the gases evolved from a series of polymers, exposed for equal periods of time in the same radiation source.

If we take the functional groups such as the phenyl groups, the methylene groups and the carboxyl groups, it can be shown that:



[the "equals or greater" sign here means "transmits to"] the phenyl groups will transmit energy to the methylene groups which will transmit energy to the carboxyl groups.[5, 7, 8, 9, 10, 11, 12]

EVIDENCE FOR FUNCTIONALITY SERIES

This is shown from a study of the gases evolved from a polymer with a 1-1 ratio of phenyl to methylene groups and from a study of a polymer with a 0.1 to 1 ratio of carboxyl groups to methylene groups respectively.

The analysis of the gases from the polymer with a 1 to 1 mol ratio of phenyl to methyl is as follows:

CO_2	0.1 mol %
CH_4	18.8 mol %
C_2H_6	0.9 mol %
H_2O	1.4 mol %
H_2	54.1 mol %
N_2	23.3 mol %
Benzene	0.3 mol %

(please turn to page 40)

the crazing of POLYSTYRENE

E. E. ZIEGLER
Dow Chemical Company

Development of a new, simplified test method has made it possible to study the effect of a great many variables on polystyrene's "critical elongation". The manner in which crazing is affected by time, temperature, reagents and exposures is discussed. While some theoretical considerations are presented, emphasis is placed on the practical interpretation of the work with the result that many heretofore puzzling behavior histories and apparent shortcomings can now be understood and explained. The presentation of the data makes polystyrene's limitations very obvious; at the same time, knowledge of the test results should lead to a more thorough understanding of polystyrene's behavior and should make it possible to design and mold better polystyrene parts, to test them for internal quality once they are molded, and to help in the development of new plastic materials.

I. INTRODUCTION —

A great many people in recent years have purchased plastic articles assuming, on the basis of visual perfection, that they were well made and trusting, from previous satisfaction with metal, glass, ceramics or rubber, that with reasonable care they would perform their intended function for an extended period of time. Some of these people have been well pleased. Unfortunately, some others have not.

Among the latter are some users of plastic kitchen utensils who, though they were careful never to pour hot grease into their clear plastic measuring cups, nevertheless watched small internal cracks develop over a period of time, expand throughout the cup, and sometimes cause complete failure. Some were users of plastic drinking tumblers who rated such items highly after several years of satisfactory service in lavatories and bathrooms but who were keenly disappointed to note internal cracking and often complete failure of tumblers used for a few weeks or months in the breakfast nook or dining room. Still others witnessed gradual degradation of such miscellaneous plastic parts as battery cases, coat hangers, brush backs, bottle closures and food containers.

The plastic parts just mentioned were "crazing."* It made little difference to the consumers whether internal molding stresses, thermally induced stresses, applied mechanical load, or chemical attack were involved, either individually or collectively. The consumers knew that these plastic moldings were not performing satisfactorily in use. They could point out that crazing was almost always associated with visual unattractiveness and in many cases with actual mechanical fracture. They had reason to be dissatisfied with such performance failures.

It was to resolve some of the unknowns in this problem of the crazing of polystyrene in particular that this work was undertaken. It was hoped that during this study a relatively simple, fast, and reproducible test method might be worked out for investigating polystyrene's crazing tendencies. In addition, it was thought that the test method, once developed, should be used for determining the stress-strain relationship and associated craze resistance of several plastic materials in air, water, and a wide variety of reagents. Finally, it was hoped that, with the general knowledge and detailed information gained from this investigation, it would be possible to make intelligent choices of plastic materials for specific end uses, to design plastic parts to function more satisfactorily over long periods of time under adverse conditions, and, when necessary, to specify such post-forming treatments for plastic parts as might be necessary to ensure long useful life.

It should be pointed out that this work was never intended to cover all the theoretical concepts of crazing, its mechanism or its relationship with polymer chemistry. It was intended to be a practical approach to an existing problem and it was hoped that the tests developed and conclusions drawn would be of practical value.

*A similar phenomenon in the metallurgical field exists in the cracking and subsequent degradation of metal parts stressed under adverse conditions; it is known as "stress-corrosion."

II. DISCUSSION —

A. Definitions

Throughout this discussion the term "stress" will be used to denote an internally distributed force in pounds per square inch. "Strain" will denote the accompanying deformation in inches per inch.

"Crazing" may be defined as fine cracks on or under the surface of a plastic. These cracks may range from those of relatively large size, individually visible to the unaided eye, down to those of almost microscopic size existing en masse as "waterbloom." Crazing is difficult to see when it is known to exist in opaque polystyrene moldings; it can most easily be seen (by reflected light) in clear or light colored translucent moldings. Crazing very often starts with the development of a few small isolated cracks; it may progress into larger patterns containing hundreds of small cracks. If a sufficient number of these join to create one or more large cracks, mechanical failure may result.

"Critical elongation" may be defined as that elongation at which, under a particular set of conditions, crazing is known to start. It may or may not progress to serious proportions, depending on several variables of exposure conditions and applied stress. The important point to remember is that whenever the critical elongation is exceeded for an adequate period of time, crazing will result. And crazing weakens any plastic molding.

B. Types of Stress

Crazing is thought to result from localized elongations of greater magnitude than the material can accept. "Stress crazing," as the name implies, is associated with stresses contained in or exerted on the plastic molding. Included in this category are such factors as:

1. Orientation stresses caused by forced molecular alignment or disturbance during the molding operation.

2. Packing stresses caused by forced injection of additional polymer during period of thermal contraction of plastic material cooling in the mold.

3. Thermally induced stresses caused by differential cooling of the plastic during the molding process.

4. Stresses caused by thermal shock on the entire molding, or by localized overheating of certain areas during machining and finishing operations.

5. Mechanical stresses resulting from externally applied load.

"Solvent crazing" is associated with the lowering of critical elongation by chemical action of a wide variety of reagents. One of many references to this in the literature explains this phenomenon as a plasticizer action which reduces the attractive forces between polymer chains so that they may pull apart at the lower strain.[1]

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[1] See Bibliography for specific reference.

Of course, it is very common for crazing to result from a combination of chemical action and mechanical stress.

C. Development of Test Method

Anyone who has had experience in the tensile testing of thermoplastic specimens (particularly polystyrene) is familiar with the development of crazing which takes place before the specimen is actually broken. That such crazing can easily be observed on standard tensile bars and that elongation of such specimens can be accurately recorded would lead one to believe that large sized, conventional testing equipment might be ideal for the investigation of crazing. Several practical difficulties prevent this from being so, among which are the difficulty of obtaining and holding an exact elongation on a given area of a test specimen, the difficulty of immersing a loaded specimen in various reagents, and the high cost of tying up expensive equipment for long periods of time for the determination of very few experimental values.

Some thought was given to the use of a simple cantilever beam of uniform cross section rigidly supported at one end and either loaded or mechanically displaced at the other end. Theoretically, this simple test setup would provide, at least instantaneously, a smooth curve and uniform variation in the specimen's per cent elongation. In actual use, it was thought that difficulties would be encountered in immersing the assembly in liquid reagents and in preventing cold flow which, as it took place, would result in constantly changing elongation.

It was thought that the foregoing difficulties would be eliminated and a simple, useful test would result from clamping a test strip of plastic over a "bending form" so designed as to provide constantly changing radius of curvature and corresponding stress as well as strain in the test specimen. By close visual examination of the stressed specimen in bright light, it would be possible to observe heavy crazing in the highly strained portions of the bar and to follow this out into the less strained portions until the location of the last significant craze mark could be established. Per cent elongations could be calculated accurately and varied over a wide range, cold flow would be essentially eliminated from consideration no matter how long the test, and the entire unit could be easily handled, transported, or immersed in reagents depending upon the needs of the test program. Accordingly, such bending forms were made up (from ½" square stainless steel) to conform to three different curves, with elongation values (on 0.125" thick plastic specimens) as follows:

Equation	Shape	Range of % Elongation
$y^2 = 6X$	Parabolic	.26 to 2.3
$y = 0.5\sqrt{400-X^2}$	Elliptical	.19 to 1.4
$y = 0.1\sqrt{400-X^2}$	Elliptical	.08 to .76

A great deal of work was done in the laboratory to establish the suitability of this test method as well as the accuracy of each bending form. The data presented in Table I are typical of the values obtained; they indicate excellent correlation between the short time critical elongation values obtained on injection molded specimens tested on a Baldwin-Southwark Universal Tester and the newly made bending forms.

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BMG-5000 Black 25 is a "universal" molding material offering these outstanding advantages:

• Unsurpassed uniformity • Better balance between cure speed and molding latitude • Suitable for compression, transfer, and plunger molding • Excellent dimensional stability and machinability • Low specific gravity • High gloss

BAKELITE Phenolic BMG-5000 Black 25 has more molding latitude and serviceability than any other general-purpose phenolic—a truly "universal" molding material. Produced by Bakelite Company on specially-engineered, automatic, semicontinuous equipment, it provides uniformity never before attained in this class of materials.

Laboratory and field tests both show that BMG-5000 molds well over a wide range of preheating and molding conditions. It has better balance between molding latitude and cure speed than earlier phenolic compounds. It does not precure as rapidly. It allows preheating at higher temperatures for longer periods of time.

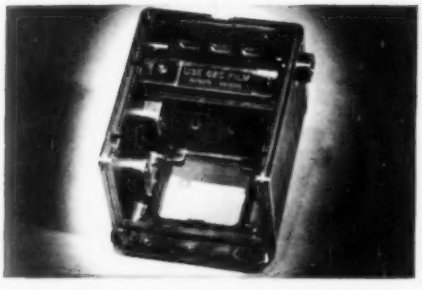
With BMG-5000, you can minimize problems caused by variations in time, pressure, and temperature in press operations. It fills out the mold at lower pressures than are needed

Fast cure of a relatively thick section is shown by this washing machine lock roller. BMG-5000 reduced curing time to 1 minute, 10 seconds, giving a saving of 22% and substantially increasing output.

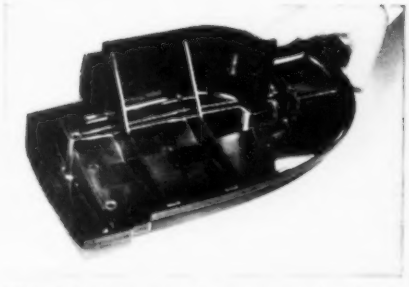
Critical dimensions of this camera case were maintained despite thick and thin sections, undercuts, and welding problems. Finished piece shows no gas marks or weld lines, meets all dimensional specifications.

BMG-5000

PHENOLIC MOLDING MATERIAL



Reflex camera case molded from BMG-5000 has intricate design to fit mechanism. Various dimensions had to be kept to close tolerances to prevent light leakage. New molding material cut cure time 28% over former material used.



This juke box part is an example of off-balance design requiring uniformly thin sections (3/32 in. thick) coupled with a deep die filling problem – it is 4 inches deep. The excellent hot rigidity of BMG-5000 eliminated sticking and swelling, and the piece was ejected from the cavity without any retarding effect.

for comparable general-purpose materials, and flows more rapidly into mold cavities, providing maximum closing speeds.

You can use this new material for compression, transfer, and plunger molding. Parts molded from it have uniformly high gloss, rich black color. Its dimensional stability is excellent during and after molding. Overall machinability is better than that of other general-purpose phenolics, as are the physical, electrical and chemical properties.

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Table I

Correlation of Bending Form and Tensile Test Results (Injection Molded Tensile Bars)

Material	Critical Elongation, % Baldwin-Southwark	Bending Forms
Styron 666	1.38	1.36
Styron 700	1.30	1.39
Q-406	1.65	1.75
Q-767	2.35	over 2.3

D. Test Specimens

One of the problems invariably associated with such an investigation is that of obtaining a large supply of uniform test pieces. That such an order cannot easily be filled by conventional injection molding practice is known from extensive experience and is referred to in the literature.[3]

It is known that frozen orientational stresses, thermal cooling stresses, and resulting mechanical strengths can vary considerably between successive "shots," even though injection molding conditions remain "unchanged." It is also known that annealing can be very effective in relieving stresses caused by thermal gradients during molding, machining, or finishing operations but that it is of little or no benefit in relieving orientational stresses involving molecular configuration.[3] Annealing of injection molded specimens was therefore thought (and subsequently proved) to be inadequate for such a test program wherein crazing is so critically affected by internal stresses as well as molecular configuration.

The fact is well known that there is considerable variation in mechanical strength with direction and amount of orientation. Whereas the tensile strength of a completely relaxed molding of polystyrene has been found to be around 5000 psi., this strength can be increased by nearly 150% in the direction of considerable orientation and can be reduced to 30% of its original value at right angles to orientation direction.[3]

Associated with the foregoing is the fact that crazing strength and orientation are directly associated. It has been reported that crazing strength can be increased by 150% or more as specimens, hot-drawn up to 230% are subsequently stressed in the direction of orientation. At values of hot stretching variously reported from 230% to 1100%, crazing no longer occurs.[3,4]

With the foregoing in mind, it was inevitable that consideration should be given to the use of unoriented compression molded test specimens. Table II summarizes the data obtained in one part of this investigation and indicates clearly the excellent correlation between the critical elongation of compression moldings and injection moldings stressed in "across flow" direction. Since injection moldings in actual use craze at right angles to the applied stress and along the lines of least strength, that is, along the flow lines, it was thought that this correlation was highly significant.

Table II

Effect of Plastic Flow on Critical Elongation (30 sec. Values on Styron 666 Clear @ 75°F.)

Reagent	Critical Elongation, % Injection Molded With Flow	Injection Molded Across Flow	Compression Molded
Air	1.66	.80	.78
H_2SO_4 (1.3 sp. gr.)	.96	.44	.43
Ethyl Alcohol	.92	.29	.24
Propyl Alcohol	.95	.56	.50
Lactic Acid	1.0	.69	.68
French Dressing	.41	.31	.30
Mustard	.91	.34	.34

Our position on test specimens can be summarized as follows:

1. Injection molded specimens are difficult to make in quantity with sufficiently uniform internal stress conditions to allow for accurate determination of critical elongation under a variety of conditions.
   a. Annealing of such specimens does not provide the desired answer.
   b. The critical elongation of conventional injection molded specimens varies as much as 100% from "with flow" to "across flow" direction.
   c. Polystyrene moldings in actual use craze along their flow lines. To duplicate this in laboratory tests requires stressing injection molded test pieces in the "across flow" direction.
2. Compression molded specimens are advantageous for this test work because:
   a. They are quickly and easily made in quantity with uniformly low internal stress.
   b. They require no careful machining or annealing.
   c. No account need be taken of direction of plastic flow.
   d. Critical elongation values on compression moldings correlate well with those obtained on injection moldings tested "across grain," which values should be useful in predicting craze-free life of molded articles.
   e. The critical elongation values thus determined are known to be practically the lowest obtainable. Thus, these low values of elongation can be translated directly into useful values of tensile stress (internally contained, externally applied, or both) below which even the weakest portion of the molding will perform satisfactorily but above which it may craze.

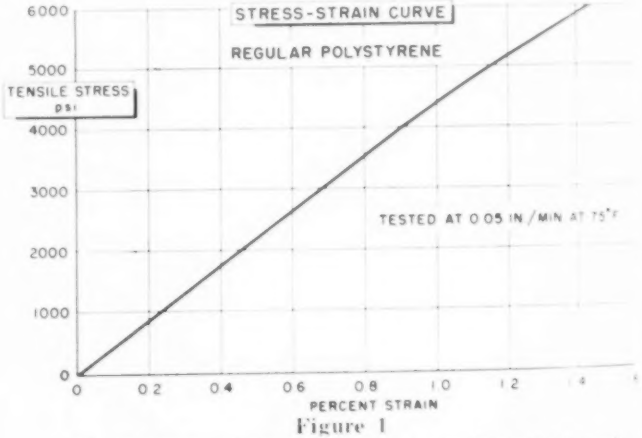

Figure 1

On the basis of the foregoing, we undertook the polystyrene crazing program by bending ⅛" thick compression molded test bars on the bending forms previously described. By very close visual observation of the test specimens on the bending forms under bright light, we determined critical elongation by observing the lowest elongation at which significant crazing took place.

III. TEST RESULTS —

Throughout the remainder of this work, frequent mention will be made of specific values of elongation of polystyrene. The significance of these values in per cent may sometimes be more readily understood in terms of tensile stress in psi. Direct reference can be made to the typical stress-strain curve of polystyrene shown in Figure 1 whenever it is desired to translate values of stress to elongation or vice versa.

A. Time Dependence

It was thought necessary, before undertaking the study of many variables and unknown factors in this problem, to determine the time dependence of crazing on polystyrene held at constant strain and constant temperature. Accordingly, this work was done over a six weeks period at 75 F air and water with results as shown in Figure 2.

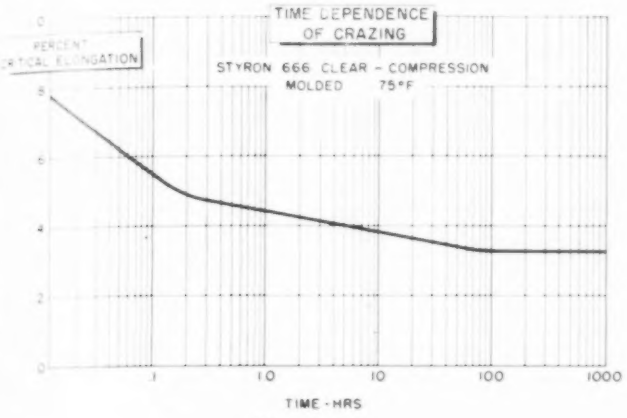

Figure 2

Unoriented compression molded polystyrene has an instantaneous (30 second) critical elongation value of 0.78%. Held under conditions of constant strain, polystyrene's critical elongation value is lowered by approximately 50% in five hours and does not reach an equilibrium value of 0.32% for approximately two days. Thereafter, no significant change takes place for one month and it is thought safe to predict that no further drop in critical elongation would occur.

It is generally agreed[1-3] that crazing is the beginning of failure in plastic moldings. This is an unavoidable conclusion when it is realized that crazing is composed of small but definite cracks or openings within the plastic material. When a craze appears, it naturally reduces the area over which the remaining load must be distributed.

The rate of penetration of crazing in polystyrene has actually been determined over a range of stresses.[4] The results can be summarized by saying that, for a given stress, craze penetration increases linearly with time and, for constant time, it increases with stress.[5] In the case of constant load application this means that, as the number and size of craze cracks increase, the unit stress becomes progressively greater on the unruptured area. Therefore, it is obviously of utmost importance in constant load applications to prevent crazing from starting, since the inevitable result of even minor crazing under these conditions is eventual mechanical fracture of the molding.

Referring again to Figure 2, it will be noted that the loss of critical elongation from its "zero" time value to the minimum equilbrium value attained after 50 hours amounts to approximately 60%. This correlates well with previous work done on long time tensile loading of injection molded polystyrene where it was learned that test bars would hold only about 40% of their rated ultimate tensile strength in long time constant load tests.

This is an important point for the designer. It emphasizes the need for a large safety factor in the design of polystyrene moldings involved in tensile loading. It also accentuates the need for more complete, actually more realistic values of tensile strength in plastics property determinations.

Actually, a polystyrene molding cannot withstand the quoted ultimate tensile stress of 6500 psi. for more than a few seconds without breaking. From the critical elongation values just quoted, it can be seen that unoriented polystyrene can withstand no more than 0.32% elongation, or approximately 1500 psi., for an indefinite period without breaking. As will be brought out clearly a little later, it will not even hold this load if the exposure temperature is raised above 75 F, or if reagents other than air or water are brought into contact with it.

The conclusions just drawn for constant load do not necessarily apply to applications involving constant strain. In the latter case the deflection or elongation is held constant; the load is not. The occurrence of a few craze cracks under such conditions may well mean that the "weak links" in the molding have been broken, that the remaining stronger portion can accept the elongation involved, and that, by virtue of some creep or cold flow, the actual stress becomes progressively lower and the molding maintains its visual appearance and mechanical strength without further change as long as the loading conditions remain unaltered. This phenomenon has been observed hundreds of times during constant strain tests on bending bars.

Much the same conclusion has been drawn by Hsiao & Sauer[6] who report that ". . . visible crazing cracks will not necessarily produce fractures but will reduce the total load the specimen can carry." They explain many of the facts pertaining to the inception, growth and location of crazing cracks in polystyrene in terms of orientation and the separation of domains[7] of molecules under the action of tensile stress.

They point out that molecular domains which are at right angles to the applied stress open up first and initiate the phenomenon of crazing. Under proper load conditions "it is possible for many crazing cracks to occur before fracture because the microopenings soon run up against other domains or groups of molecules not so favorably oriented for separation and then they are automatically halted."

The important effect of orientation on crazing and tensile strength is further emphasized by the fact that these domains can carry considerable stress in their longitudinal direction but only very little stress in the transverse direction. Thus when tensile stress is applied in the direction of orientation to specimens previously oriented to say 1000%, crazing is not observed because there are no domains left oriented at right angles to the tensile stress and the fracture, when it occurs, is of a fibrous type.[8-10]

B. Temperature Dependence

The variation of polystyrene's critical elongation in air or water over a wide temperature range is shown in Figure 3. Above the freezing point of water, the time required to reach minimum equilibrium elongation is inversely proportional to the temperature. It is expected that the critical elongation would continue to drop with increase of temperature until the ultimate elongation of the material would rise as it softens near its heat distortion point. Above this temperature, critical elongation has no practical significance.

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[7] A "domain" is described as a group of molecules arranged together in more or less cylindrical form with the various long-chain molecules essentially parallel to one another within the group.

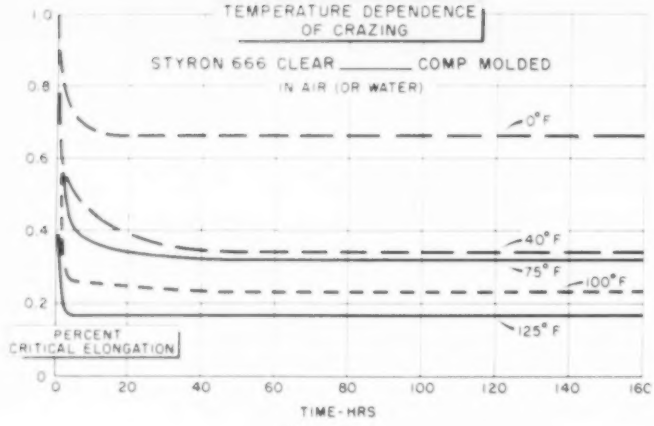

Figure 3

C. Craze "Healing"

The rather limited work on healing of visible craze cracks done in our laboratory confirms previous work reported in the literature.[1,8,10,11]

It seems generally agreed that crazing cracks tend to disappear with time after removal of stress when stored at some elevated temperature. Internal and external crazing in injection and compression molded specimens did not heal visibly in 1000 hours at 75°F. with test bars crazed in air, in methanol and in normal heptane. At 170°F., however, the visible healing which took place within 100 hours was noticeable and within 600 hours was nearly complete. Unfortunately, little or no mechanical strength was regained so that the only beneficial effects were in the visual appearance of the moldings.

It is well known that polystyrene moldings stressed in pure compression do not craze. Repeated and prolonged compressive stress on previously crazed moldings is effective in visual healing but ineffective in restoring original mechanical strength.

Exposure of similar moldings at a temperature just above the second order transition point, that is at 185°F., resulted in visible healing within twenty-four hours. In many cases the visible healing was complete within 100 hours and was accompanied by an appreciable regain of mechanical strength as well. Unfortunately, exposure of most moldings of regular polystyrene to 185°F. for any length of time results in such objectionable deformation as to render the treatment relatively useless from a practical standpoint.

D. Effect of Reagents

So far this discussion of test results has been limited to the crazing of polystyrene in air (or water). Of considerable importance from the practical standpoint is the crazing of polystyrene in a variety of reagents, on the cause of which many hypotheses have been offered. Actually, the precise mechanism whereby chemical reagents cause crazing cracks to originate and to grow is not well understood.

It is possible that the effect depends upon absorption of the reagent by the surface layers of the polystyrene. The reagent may then act as a plasticizer, further entering the polystyrene molding and reducing the attractive forces between the chains so that they may be pulled apart[1] or slipped against each other more readily.

Regardless of the precise mechanism, the crazing pattern of an actual molding would be expected to differ from that obtained on a test specimen stressed in pure tension. Instead of forming a regular system of parallel cracks at right angles to the applied stress, the crazing might be expected to follow a pattern indicating the localized combinations of highest internal and applied stress with lowest internal strength.

Thus, crazing cracks might be expected to develop along flow and weld lines in injection molded articles by virtue of some internal stresses being present at right angles to direction of plastic flow. This crazing can be accelerated and aggravated by the application of certain reagents, either in handling, finishing, or actually using the finished moldings. Of course it can also be accomplished by deliberately immersing the moldings in various liquid reagents.

For example, highly internally stressed wall tiles, subjected to chemical action by a particular mastic or solvent type "cleaner," develop crazing cracks along the lines of plastic flow emanating from the gate and progressing across the flat face of the tile as well as around the edges where the internal stresses are high. Drinking tumblers, used for some period of time with milk or hot beverages, develop cracks long their flow lines, starting with radial cracks out from the gate on the center of the bottom and progressing across the bottom and up the side walls. Back painted moldings, in contact with lacquer solvents for a relatively brief period of time, develop cracks along their flow lines if the combination of internal stress intensity, orientation, and lowered critical elongation are such as to produce crazing.

The bending form test, utilizing practically stress-free compression moldings, is particularly useful in determining relatively quickly and easily to what extent polystyrene's critical elongation is lowered in contact with various reagents. By the proper use of knowledge thus gained, it is possible to determine the actual internal stress in a molding. It is possible to determine accurately the benefits derived from annealing stressed moldings. It is possible to predict the effect of external loads, contact reagents and use conditions on the crazing tendencies of various moldings. And it should be possible to use this knowledge to design and also to mold better plastic parts.

It will be remembered from Figure 3 that minimum equilibrium critical elongation of polystyrene in air (or water) at room temperature is 0.32% and is not reached until about 50 hours of stressing time have been completed. Thereafter, no further loss in critical elongation would be expected.

The time-crazing effects of other reagents on polystyrene vary widely, depending upon the nature of the reagent, as shown in Figure 4.

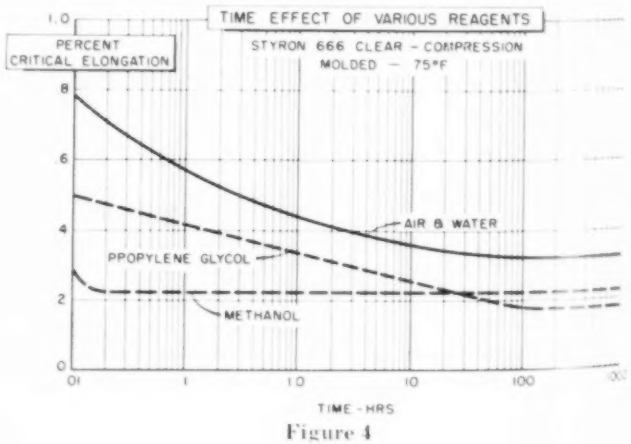

Figure 4

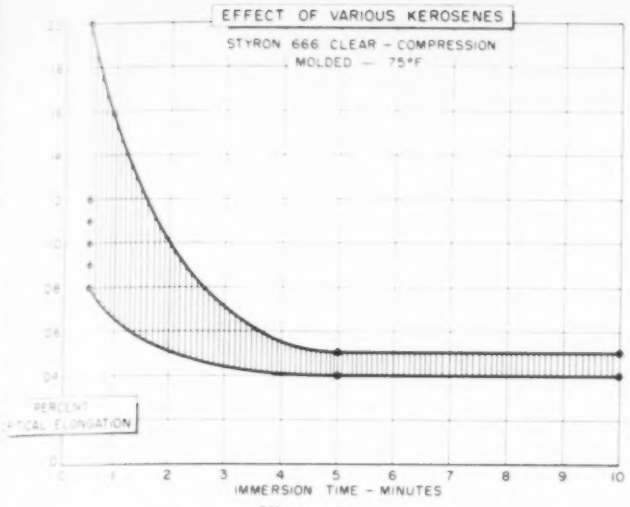
EFFECT OF VARIOUS KEROSENES
STYRON 666 CLEAR - COMPRESSION MOLDED — 75°F
PERCENT CRITICAL ELONGATION
IMMERSION TIME - MINUTES

Figure 5

1. Miscellaneous

Propylene glycol, for instance, takes at least 150 hours to reduce polystyrene's critical elongation to a minimum equilibrium value of 0.18%, which corresponds to a stress of about 800 psi. This information is useful in explaining why some moldings craze when immersed in propylene glycol for the determination of heat distortion temperature or for purposes of annealing. It should be borne in mind that these values of elongation and allowable stress would be depressed still further upon immersion at temperatures well above 75° F.

Methanol is very fast acting; it requires only a few minutes on the stressed area to reduce polystyrene's critical elongation to the equilibrium value of 0.23%, corresponding to a stress of about 1000 psi.

Fingerprints directly on a stressed surface result in a depression of critical elongation to 0.35% in 30 seconds and in some cases down to 0.11% (500 psi.) in long time tests.

2. Kerosene

The use of kerosene for determination of stress level in molded polystyrene parts has been debated for years. There are some who believe such a test to be valuable; there are others who disagree. In order to determine accurately the effect of such liquids on polystyrene's critical elongation, samples of high and low grade kerosene obtained from various sources in the United States were used in bending form tests.

"Instantaneous" values of critical elongation varied widely as shown in Figure 5, apparently substantiating those objecting to the use of kerosene on the basis that it was not a chemical entity, that no two kerosenes were exactly alike, and that results on polystyrene's crazing tendencies could be neither trusted nor reproduced.

Long time equilibrium values of critical elongation showed an appreciable narrowing of this range, actually down to the point where the use of kerosene for crazing tests could be justified, if the time interval of testing is of sufficient duration, and if "range oil," "heater oil," or "distillate" are not substituted for kerosene. Results over a period of time showed that polystyrene moldings stressed above 200 psi. would craze in contact with kerosene.

3. Normal Heptane

There has recently been rather wide acceptance of normal heptane as a "cure-all" immersion test for polystyrene moldings. Proponents of its use have immersed moldings weighing from a few ounces up to several pounds in normal heptane at or near "room" temperature for times varying between a few seconds and thirty minutes, in most cases without knowledge of the exact effect of such immersion.

Figure 6 shows the effect of pure normal heptane on polystyrene at three temperatures. It will be noted that temperature and time of immersion are variables of considerable importance. Of further significance is the fact that normal heptane is very effective in lowering polystyrene's critical elongation, so effective in fact that stresses above 50 psi. will cause crazing at 90° F.

Laboratory tests have proven that normal heptane, once applied to a polystyrene surface, is not easily removed. Evaporation soon removes the surface excess but apparently the penetration of a small portion into the molding continues to depress the critical elongation long after actual immersion has stopped. It is known that after immersion of a molding normal heptane is still retained internally after one week's "drying" time at 75° F. and 50% relative humidity.

In our opinion, testing polystyrene parts in normal heptane should be undertaken only after the operational details and significance of the test are thoroughly understood and preferably only after correlation with actual end use has been established. Otherwise more harm than good may result.

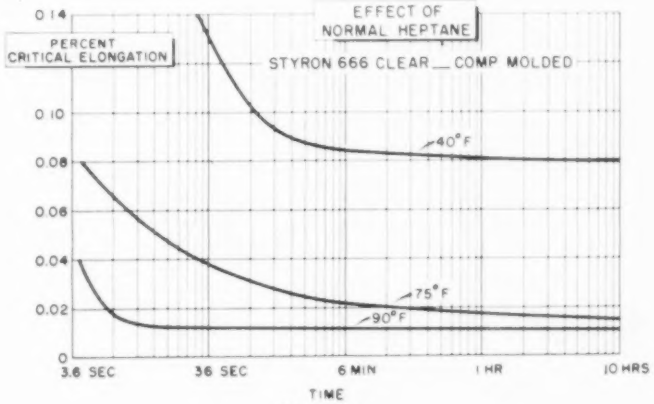

Figure 6

4. Dairy Products

It will be noted from Figure 7 that lactic acid requires over 100 hours on the stressed area to reduce the critical elongation of polystyrene to its minimum value

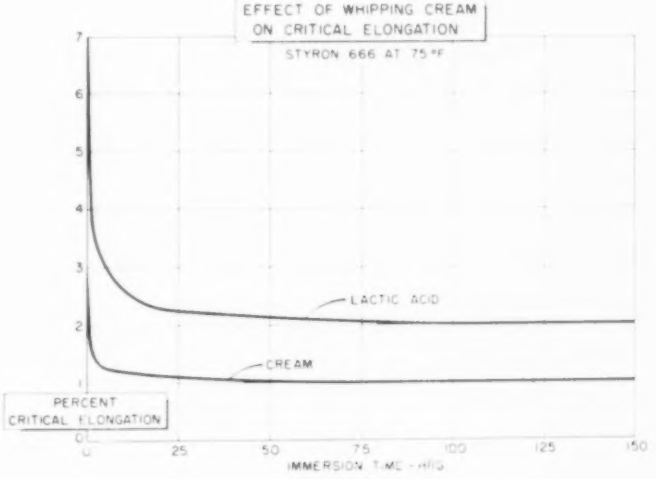

Figure 7

of 0.19% at 75°F. It will also be noted that cream, containing a percentage of butterfat, causes a reduction of critical elongation down to 0.10% in about 100 hours at 75°F. Lactic acid is present in small amount in fresh milk. Butterfat is present in milk in varying amount, ranging from low in the case of skim milk to high in whipping cream.

The data in Table III show the effect of dairy products on polystyrene's critical elongation after 30 seconds' application at 75°F., as well as after extended contact.

Table III

Effect of Dairy Products and Constituents on Critical Elongation (at 75°F.)

	30 Seconds Application		Long-Time Application	
Reagent	Critical Elongation	Critical Stress	Critical Elongation	Critical Stress
Water	.78%	3500 psi.	.33%	1500 psi.
Lactic Acid	.69	3000	.19	850
Skim Milk	.64	2800	.17	750
Homogenized Milk	.44	2000	.14	600
Condensed Milk	.34	1500	.12	550
Cream	.29	1300	.10	450
Butter	.29	1300	.10	450

Obviously the lactic acid has relatively less effect in weakening polystyrene than butterfat, whose major effect is undoubtedly the cause of the relatively short life of average polystyrene tumblers used regularly with milk products.

In actual use some thermal stresses would be set up in a polystyrene tumbler as cold milk was poured into it. At low temperature the damaging effect of fat would be less severe, but as the temperature rose the effect would be more severe. Reference to Table III shows that if the stress on tumblers used for some time with milk were over 450 to 600 psi. at 75°F., crazing would result.

In normal use, a thin layer of milk (and fat) would still be on the inside walls of the tumbler when it was submerged in hot dishwater. At a temperature of 125°F. the critical stress would be still further depressed to a level of about 300 psi. In scalding rinse water a stress of about 200 psi. would be sufficient to initiate crazing and a good portion of this could be created by the thermal shock of the hot rinse itself, leaving very little allowable room for accommodation of internal molding stresses, or mechanical loading stresses resulting from stacking, rough handling or accidental dropping.

It would be natural to assume that the deleterious effect of milk or cream would be limited to the time interval of actual contact and that, once washed, the process would naturally start over from the beginning. Unfortunately this is not so. The effect of such contact, intermittent or continuous, is cumulative. The critical elongation of a polystyrene molding has been shown to be the same no matter whether it is immersed in milk or cream in stressed condition for a given time interval or immersed in totally unstressed condition, washed in soapy water, dried for twenty-four hours, and then stressed for the same time interval.

Apparently there is some penetration into the polystyrene, even by relatively viscous fats and oils, which makes removal by surface washing a practical impossibility. This penetration and the cumulative effect on the depression of polystyrene's critical elongation explain why tumblers may be used with milk for weeks or months without visible evidence of damage and then, under the same use conditions, start to craze, and perhaps finally crack open in complete failure.

In our attempt to evaluate polystyrene tumblers and to help molders improve the quality of their products, the serious problem arose of devising new laboratory tests which would correlate with actual use. It was not until an eight months' use test on several types of plastic tumblers was conducted among 750 families (statistically balanced by nationwide United States Census figures) and elaborate questionnaires were returned and summarized that such a correlation became possible.

We are now able to determine in a few minutes by specialized laboratory tests whether any polystyrene tumbler is up to what this nationwide poll rated an acceptable standard of quality.

5. Hair Preparations and Oils

Conflicting reports were received from the field not long ago concerning the failure in actual use of polystyrene hair curlers. The failures, always associated with crazing of the curlers after extensive use, were attributed to insufficient impact and flexural strengths, inadequate heat distortion, excessive molding stresses, and off-grade raw material.

Our investigation of the effect on polystyrene's critical elongation of the various hair preparations used in beauty parlors led to the conclusion that as far as polystyrene was concerned these creams and liquids were relatively harmless. It was then discovered that natural hair oils lowered polystyrene's critical elongation much more severely than any of the prepared lotions, and that the damage was equally as severe immediately after washing the hair as before. The supporting data for this work are shown in Table IV.

Table IV

Effect of Hair Lotions (On Styron 666 @ 75°F.)

	Critical Elongation, %	
Reagent	30 sec.	20 min.
Air or water	0.78	0.48
Type A Cold Wave	0.82	0.45
Type B Cold Wave	0.75	0.43
Type C Cold Wave	0.74	0.37
Cream Fixative	0.72	0.34
Powdered Bleach Solution	0.71	0.33
Lanolin Wave	0.69	0.39
Natural Hair Oil	0.24	0.15

The difficulty was made more serious by the fact that considerable mechanical stress was placed on the curlers during actual use and the temperature, instead of being 75°F., was a high as 185°F.

Solution of the problem came from a change of materials, not to high impact or high heat types, but to a Dow chemically resistant plastic formulation (with high heat distortion) known as Q-767 which had three times as high a critical elongation under identical conditions.

It is obvious that polystyrene combs, in prolonged contact with hair oil, suffer the same effects over a period of time and can finally withstand a tensile stress of only 700 psi. or less. Substitution of Q-767 for any regular polystyrene should result in much improved combs with greatly extended craze-free use life.

6. Wall Tile Cleaners

Complaints have been received from the field at various times stating that plastic wall tile mounted on a wall were developing cracks under certain conditions. On one occasion it was shown that the design was such that internal stresses of serious magnitude were responsible for the difficulty. On another occasion it was shown

that the high molding stresses incorporated in the tile could be relieved by annealing and that crazing of the tile in service could be practically eliminated.

Many of the crazing and cracking problems have been traced back to the use of various tile "cleaners" for removing excess mastic and imparting a polished (and sometimes a destaticized) finish. The data in Table V show the wide variation in the effect seven commercially available cleaners have on polystyrene's critical elongation in just 30 seconds of application time.

Table V

Effect of Wall Tile Cleaners
(on Styron 666 @ 75° F. for 30 sec.)

Cleaner	Critical Elongation, %
Air or Water	0.78
Type #1	0.34
Type #2	0.28
Type #3	0.26
Type #4	0.21
Type #5	0.16
Type #6	0.15
Type #7	0.06

It was no wonder that some tile were cracking when high molding stresses, application stresses and thermal expansion stresses were all at work on moldings severely weakened by contact with some mastics and cleaners.

It is hoped that, as this new technique for determination of critical elongation is developed and used more widely, new and greatly improved specifications for wall tile mastics, cleaners and destaticizers may be written and that quality standards may thus be more effectively measured and enforced.

E. Effect on Various Exposures

Sufficient data are not yet available to list the long time equilibrium critical elongation values resulting from exposure of polystyrene to a variety of conditions. Short time tests have been conducted, however, and the results are tabulated in Table VI.

Table VI

Effect of Various Exposure Conditions
on Styron 666 @ 75° F. (Tested for 30 sec.)

Exposure	Time, Hrs.	Critical Elongation (30 seconds)
None	0	0.78
Dark oven @ 170° F.	850	0.72
Fluorescent light-(standard white)	850	0.77
"Black light"	850	0.70
Weatherometer	100	0.78
	200	0.73
	450	0.68
Fadeometer	100	0.76
	200	0.70
	450	0.66
Germicidal light	200	0.51
	450	0.45
G.E. Sunlamp @ 140°F.	200	0.45
	450	0.33

It is clear from these data that there is an appreciable effect on the critical elongation of polystyrene resulting from exposure to various light sources. It is apparent that prolonged heating in the absence of light does little harm as long as stress is not applied to the molding until it has cooled down. It is also apparent that as the wavelength of the light decreases and as accompanying temperature increases, the adverse effect on critical elongation becomes more pronounced. The latter combination helps to explain why polystyrene and other plastic moldings craze so markedly during exposure in Arizona.

F. Effect on Electrical Properties.

The question frequently arises, "Are polystyrene's electrical properties degraded by craze marks?" The answer is, "No, not unless there are entrapped contaminants." The data in Table VII bring this out clearly.

Table VII

Effect on Electrical Properties
Injection Molded Styron 666 Clear @ 75° F.

Condition of Specimen	Dissipation Factor at 10⁶
As molded	.0001
Crazed (while stressed) in normal heptane	.0006
Stored one week @ 75°F. and 50% R.H.	.0006
Dried in oven 24 hrs. @ 150°F.	.0001
Soaked 24 hrs. in water @ 75°F.	.0007
Dried in oven 24 hrs. @ 150°F.	.0001
Stored one week @ 75°F. and 50% R.H.	.0001

G. Effect of Finishing Operations

It would appear that, as times goes on, more and more polystyrene moldings are being subjected to a variety of finishing operations. In some cases these operations are conducted without contact with reagents and without a rise in temperature and hence with no difficulties from crazing. In other cases crazing may result from one or more of the following possibilities.

Machining molded parts may involve drilling, sawing, tapping or milling. If these operations are not very carefully done, localized overheating may result and, if sufficiently serious, may cause the development of craze cracks. Liquid coolants must be chosen carefully if further damage to the stressed molding is to be avoided.

Fastening various parts together may be accomplished by the use of adhesives. There are many formulations of adhesives available for such work, each with different "solvent" ingredients. It is important that the proper adhesive be used in critical jobs and that adequate (but not excessive) clamping pressure be employed to effect a good bond without initiating crazing.

In a somewhat different sense, "fastening" may be accomplished by the use of self-tapping screws, rivets, bolts, hinges, spring clamps or snap fits. It is fundamentally important for the designer to keep polystyrene's critical elongation in mind in designing such moldings and specifying such parts. It is equally important for the workman on the job to mold the article without excessive stresses and to assemble the parts with sufficient care to prevent the localized overstressing of certain areas and the attendant development of crazing.

Buffing, if carefully done, may produce the desired effect of imparting a high polish to previously marred areas of a molding. If carelessly done, it may produce undesirable localized overheating and subsequent development of craze marks, particularly if a polish is used which effectively lowers polystyrene's critical elongation.

We have already shown the serious effects which some lacquers have on the critical elongation of polystyrene. This points out the two-fold need of designing and molding the part so that a minimum of internal stress exists and also of choosing and appiying a lacquer so that adequate adhesion may be attained with minimum loss of elongation.

A final point well worth mentioning is the need for careful selection of protective covering or tapes intended for direct application to finished parts. Innocuous looking

(please turn to page 42)

why more plastics?

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It is permissible very occasionally to look backwards as well as forwards and to try and learn from the past what the future holds. This is a somewhat presumptuous task as the modern plastics industry is so young that many of us, myself not excluded, have seen every modern plastic all the way from the test tube.

The title of the paper is intended to be provocative and at the end I shall try to give my answer. The question "Why More Plastics?" raises several others, and all through the paper I shall have them in mind.

CAN WE DO MUCH MORE with the present plastics? Is it desirable to have more plastics? Is it possible to do so? Can more plastics be justified on economic grounds?

First let us run over the names of the polymers which have risen to prominence in the last 20 years or so—polyvinyl acetate, polyvinyl alcohol, polyvinyl chloride, polyvinylidene chloride, polyvinyl benzene, polyvinyl cyanide, polyisobutylene, Neoprene, butadiene copolymers, polymethyl methacrylate, nylon, polythene and polyesters including polyethylene glycol terephthalate. The discoveries which led to these polymers, and to others which I shall mention in a moment, can be traced directly or indirectly to the pioneer work of two men, one still happily with us and the recipient last year of the Nobel prize for chemistry. These men are Staudinger and Carothers. Staudinger coined the word "macromolecule" and much of what the prefix "poly" means to us is due to his investigations. Carothers speculated with equal courage and worked in the laboratory with equal skill to establish new concepts and to devise new methods for making long-chain polymers. He built brilliantly on the work of Emil Fischer and founded the synthetic textile industry.

The polymers we have mentioned are the giants of the modern plastics industry. Others, not yet so important, but rapidly gaining in industrial status, are those containing fluorine and silicon respectively; the polyethers; and isocyanate rubbers. We read too in the literature of dozens of other compounds which have been tried for the preparation of plastics on a laboratory scale. All the materials so far mentioned, with the exception of the silicons, have in common the -C-C- skeleton. Few of them can be used at temperatures above 300°C, and not many can be exposed to the weather for more than a year or two without deterioration. Perhaps a way may be found of strengthening the C-C link—after all the diamond, which consists of pure carbon, is highly resistant to temperature—but, at present, there are no hopeful signs and the C-C link, a source of weakness as well as strength, can be ruptured by sunlight or simple mechanical treatment.

The very mention of so many new plastics suggests that the industry is a large one, so perhaps before going further we should get it in perspective. On the next page are listed approximate U.S.A. annual outputs for 1949 of some important materials.

Looked at from this point of view, plastics seem rather small beer, but it must be remembered that the rate of growth in the plastics industry is greater than that in all the other industries mentioned. There is indeed some evidence for the belief that in about 30 years' time the polymer industry, including that of wholly synthetic fibres and synthetic rubbers, will have increased to about 10 times its present size. It will then be so big that the raw materials problem will be a pre-occupation of those then running the business. There may, indeed, be a few of them here today.

When plastics are produced on such a scale, assuming that the raw material problem has been solved and that technical progress has uncovered cheaper syntheses, high price will no longer be a brake on consumption. The importance can indeed be exaggerated now. Many expensive plastics are cheap on a volume basis and can compete with metal, e.g., during the Korean war a part of a well-known safety razor made from nylon part was almost as cheap as the metal temporarily replaced.

Now that we have got the industry in perspective we can return to future development. Out of many new plastics being studied in the laboratories of the world, it is quite certain that there are one or two whose special properties will command commercial success but, as far as we can see at the present, these new materials will not differ in any spectacular way from the old ones. The carbon chain will still be the skeleton and the differ-

properties will not be great although no doubt important commercially.

New plastics then there will be, but not the great galaxy which astonished us in the early 1930's. A flood of invention and discovery in the plastics industry is not likely to sweep over us again. It is particularly doubtful if any of the new plastics will be cheap. The trend is indeed all the other way. Look at the recent additions mentioned—the polyethylene glycol terephthalate polyesters, the fluorine plastics and the silicon plastics—all are quite expensive materials and likely to remain so even if made in much larger quantities. Put in a different way, what I am saying is that Beilstein has been almost completely mined and no new source of information is open to the organic chemist. This is not because of lack of academic effort or because imagination has diminished since the 1830's when so many of today's plastics were made in test tubes, only to lie there for nearly 100 years. It is true there is a peculiar disparity today between the amount of money spent on academic research and industrial research. Industry quite wrongly even for its own good, spends annually much greater sums than those allocated to the Universities. Both sums are, however, very large and dwarf the petty outgoings of the last century. It is probably also true that, for the young scientist, organic chemistry has lost its charms. The present fashion is more for splitting the atom. In making these pessimistic prophecies it must, however, be remembered that "the demise of organic chemistry has," in the words of Sir Robert Robinson, "been confidently predicted for the last half century." Sir Robert in his Priestley Medal Address[1] to the American Chemical Society last year takes an optimistic view: "Among the most spectacular of the achievements of the past 20 or 30 years, largely due to the work of American chemists, must be counted the modern refining and molding of petroleum for various purposes, and its use as a source of other substances. With the associated studies of heterogeneous catalysis and macromolecular science, the scope for further discovery is unlimited. The tour de force executed by Reppe in his work on acetylene derivatives during the last world war, and the still more recent discovery of novel reactions of the simple olefins by Ziegler and his colleagues, show that there are as good fish in the sea as ever came out of it." Perhaps my conclusions are wrong. Let us hope so.

If there are going to be no spectacular new plastics until a radically new approach has been made, what are the big changes in the industry going to be? One of the most important trends is towards quality, uniformity and standardization, all quite closely linked. One of the big troubles of plastics is that good materials can be made into bad articles by fabricators out for a quick return. In the older materials there is a tradition of workmanship and perhaps more knowledgeable buyers fully conscious of specifications. In the plastics industry more specifications and more hall-mark schemes are urgently needed. Changes in these ways will come about perhaps because the industry will learn at last that honesty is a fairly good policy, and because the physicist will increase our understanding of the structure of plastics and how to control it. I am thinking particularly of the newer form of plastics and of the elegant work which has led us to know why they behave as they do. The words "crystallization" and "texture" are creeping into the vocabulary even of hard-hearted business men. Here the plastics industry has borrowed considerably from the fibres physicists. Crystallization we all know about. We know that synthetic fibres came of age when Carothers stretched nylon and found that not only did it stay stretched but that the properties were improved. The phenomenon of crystallization by stretching has, of course, been familiar to the rubber chemist for many years. Rubbers have indeed been described as "fibres above the melting point." Rubbers are not materials with mysterious properties but simply collections of molecules of the right length and flexibility with little intermolecular attraction. It is now becoming clear that crystallization phenomena are of great practical importance and affect the properties of many thermoplastics. In most of them the crystals are discontinuous—in other words, the chains are sometimes ordered and sometimes disordered. The regions of high crystallinity can be regarded as fillers for regions of low crystallinity, just as carbon black of the right particle size is a reinforcing filler for rubber.

The concept of texture is a fairly recent one. The texture of a polymer arises from the crystalline amorphous ratio, from the way in which the crystals grow, as well as from the degree of orientation of the molecules.

One very simple method of determining the crystalline/amorphous ratio is by measuring the density. The crystalline amorphous ratio of an average specimen of polythene is, for example, about 55/45 by weight. Other methods give higher figures. A high degree of crystallization is not, however, necessary or desirable in all long chain thermoplastic polymers. Polythene at least 95% crystalline has been prepared from diazo methane and it is indeed to the polythene side chains, which make some areas irregular and therefore not susceptible to crystallization, that polythene owes some of its mechanical properties. There is still much to learn about the importance of the crystalline amorphous ratio; for example polyacrylonitrile is mostly amorphous and polyvinyl alcohol mostly crystalline and both are important fibre-forming polymers.

A deeper knowledge of these phenomena will widen the scope of these thermoplastics. So, too, will the new techniques of which there are many—grafting and irradiation, to mention only two. Irradiation is perhaps causing most interest at the moment because the claims made for it are so sensational. The work in the U.K. was initiated at Harwell atomic centre where it was shown that some plastics when exposed to neutron bombardment are changed in a remarkable way. For example, polythene becomes crosslinked after a moderate dose and hard and brittle after a heavy dose. The time of exposure is short and the effects homogenous. Polymethyl methacrylate, on the other hand, becomes yellow and degrades so that, at the end of the experiment, the sample is almost foamed. Atomic piles are not yet common, so perhaps the future commercial application of the idea lies in the 8 to 10 m. volt machines being developed in the U.S.A. and

(please turn to page 41)

	m. short tons
PLASTICS, excluding protective coatings and fibers	0.5
ALUMINUM	0.6
LEATHER	1.0
CERAMICS	1.5
RUBBER	1.6
ZINC AND COPPER	3.7
GLASS	5.4
TIMBER	45.0
STEEL	78.0

the EXTRUSION of film and sh

GEORGE D. KOVACH
The Foster Grant Company, Inc.

OF ALL THE METHODS used to form thermoplastic film and sheeting, extrusion is the newest and the fastest growing.

Some years back cellulose acetate film and sheeting were manufactured by pressing a block from a mixture of the plastics and solvents. The block was then put in a slicer where it was cut into individual sheets. These sheets containing solvents had to be cured for a period of weeks and afterwards press-polished. Therefore the manufacture of cellulose acetate sheeting required buildings of fireproof construction, heavy duty dough mixers, the block presses, the skivers or slicing machines, the curing houses and the polishing presses for the finishing operation. Besides all this investment in equipment, a very large working capital was required since it took approximately eight weeks from the purchase of the raw material until any finished sheeting could be shipped.

By the extrusion method the cellulose acetate plastic compound is fed into the extruder and the finished sheet or film taken off. Not only did the extrusion method eliminate a lot of steps in the manufacture, reduce the capital investment, but it extended the range of the product. Where the old method was limited to a lowest gauge of .008 to .010", by extrusion, film down to .001" can be manufactured. This case history is a good illustration of how extrusion of film simplified an industry.

POLYETHYLENE AN EXTRUSION BOON

When polyethylene appeared on the market, extrusion really came into its own, since there was no other practical method for making polyethylene film or sheet, but extrusion. With the rapidly expanding importance of polyethylene in packaging, this has given birth to an entire new industry.

Another important development in the history of film extrusion was the growing importance of vacuum forming from rigid thermoplastic sheet. It soon became obvious that in order to compete with injection molding, and make vacuum forming a really economical method of fabrication, the processor would have to extrude the sheet in preparation for the forming operation. All high-impact styrene sheet used for vacuum forming today is either extruded by the raw material manufacturer, or directly by the vacuum former in a semi-continuous operation. This method made it possible to make deep embossed P.V.C. placements a large volume item. The plasticized P.V.C. sheeting is extruded onto a vacuum forming drum where the finished placemat is produced in a single operation.

Such an obvious advantage as continuous deep-embossing made manufacturers interested in the extrusion of P.V.C. film and sheeting. The reason for earlier lack of interest in extrusion laid in the ease with which P.V.C. can be calendered.

There are two good reasons why this field is finding such widespread interest in the plastics industry today. The first is the tremendous investment involved in a calendering plant. The second, and gradually becoming the most important reason is the extension of the useful range of plasticized P.V.C. Calendered P.V.C. film below .005" has very poor strength characteristics, whereas extruded film is excellent down to .001" and lower. The first table will give an idea of the difference.

Extrusion of Polyethylene film through a flat die.

TABLE I

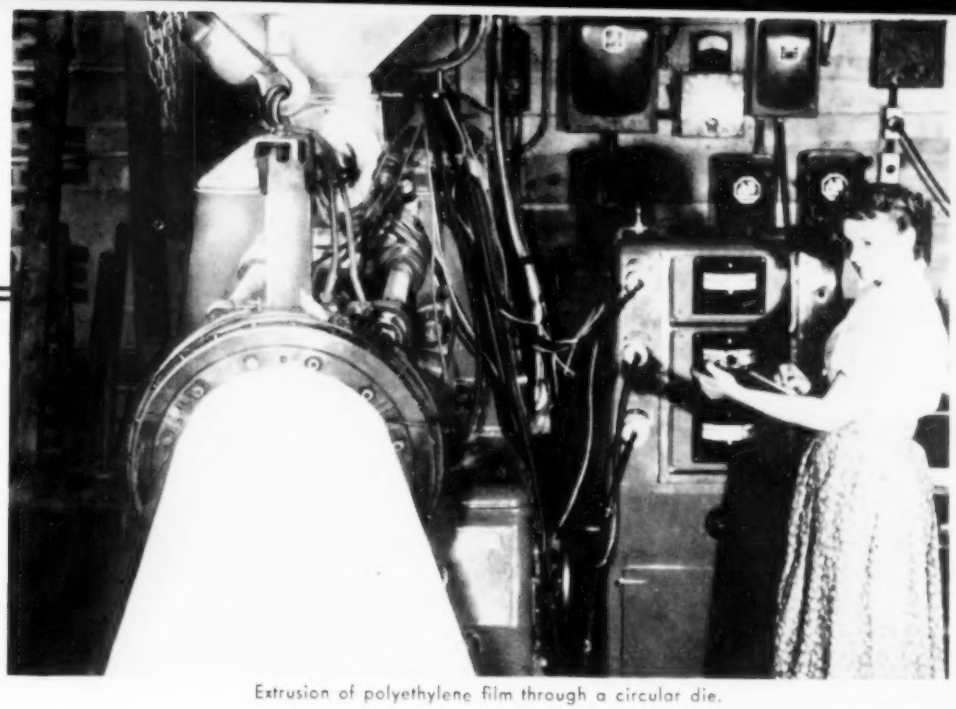
	Gauge Mils	Elmendorf Tear Grams	Pistol Bags. p.s.i.	per lb.
Extruded Vinyl	2.5	123	1850	32
Calendered Vinyl	4.0	44	380	16

Same formulation of P.V.C. films .002"

	Calendered	Extruded
Tensile p.s.i.	2000	2300
% Elongation	120	180
Elmendorf Tear p.s.i.	210	540
Average Tear lbs./in.	170	645

Besides the very important gains in strength and quality in extruded film against calendered film, another very important advantage can be gained by extrusion. Whereas calendered film always shows a frosty appearance, extruded P.V.C. film can be made completely clear and glossy.

...d sheeting



Extrusion of polyethylene film through a circular die.

This will open up great possibilities for P.V.C. in display packaging, and many other applications.

METHODS AND PROBLEMS IN FILM EXTRUSION

Now we have covered in a very sketchy way the reasons for the growing importance of extrusion as a method for manufacture of film and sheeting. Let us go into methods and problems involved in the process.

From the point of view of methods, we can divide the field into two major groups:

(a) Rigid film and sheeting.

(b) Flexible films and sheeting.

The first group we will not discuss in detail since it was covered at the Chicago SPE Conference two years ago by Mr. Blackard, and was covered again during the Toronto meeting. In general terms, there are two methods for extruding of rigid sheets. First is extrusion through a circular die. By this method the sheeting emerges in the direction of the extruder barrel. The best known method slits the tube right at the die at its lowest point and opens the sheet up and over a number of bowed spreader bars. Generally, a circular die will be less costly than a flat die, and it is easier to obtain uniform heat throughout a circular die. It is conceivable that unplasticized P.V.C. could be extruded through a circular die of this sort, but to my knowledge very little, if any, work has been done in that direction.

This method has been used for years with great success. Nevertheless the extrusion of rigid sheet from a flat die is gaining in popularity since it lends itself to the performance of after-forming operations like embossing or vacuum forming right at the point of extrusion, in this way making it possible to utilize the heat with which the sheeting emerges from the extrusion die. For this reason, I am sure that we will see more and more development work in this direction during the next few years.

When extruding cellulose ester sheeting some provisions have to be made to prevent surging, which results in gauge variations. The first factor in this respect is screw design, since a torpedo on the front end of the screw will do much to heat the stock more thoroughly and uniformly, reduce gel particles and prevent surging. Additional improvements can be made in proper die design, where a small reservoir will serve to even out pressure. Coming from a flat die of this sort many different types of take-offs can be used. The sheet can be extruded onto a conveyor belt or into the bite of heated or cooled steel rolls or around a single large steel roll of controlled temperature. The gauge across the width of the sheet is adjusted by moving the blades of the die doing the final forming of the sheet.

EXTRUSION OF FLEXIBLE SHEETS

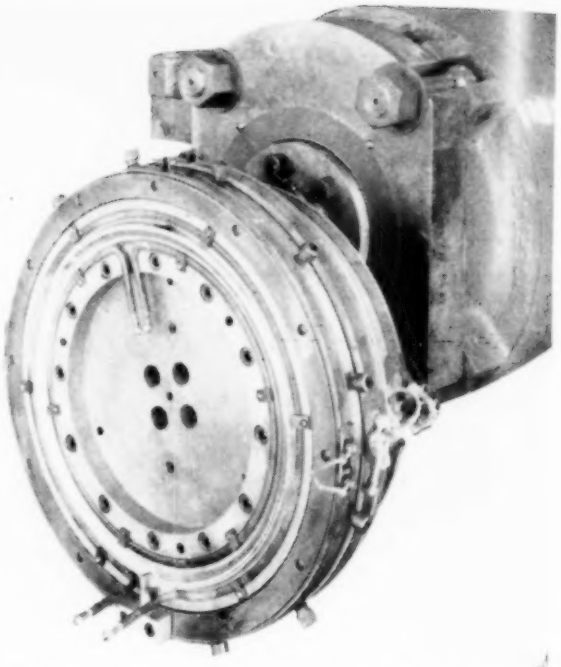
The most important items for the extrusion of flexible films and sheeting in this field today are polyethylene and plasticized P.V.C. Even though the basic methods used for the extrusion of both are more or less the same, there is sufficient difference in the behavior of the two materials to pose completely different problems to the extruder. Polyethylene at least does not present a problem until it enters the extruder. The raw material does not vary much in particle size, the molecular weight is fairly constant and outside of lubrication and coloring matter nothing has to be added. Polyethylene has practically unlimited heat stability and excellent flow properties under heat and pressure. Therefore the problems involved reduce themselves to high and efficient output, good gauge control, heat control, and satisfactory take-up and winding equipment. Now let us discuss these factors point by point.

The output of the extruder depends on two factors. The first factor is a long enough barrel to bring the material into a uniformly heated stage at a sufficient rate. Since polyethylene is an extremely poor conductor for heat, it will require a long barrel and a fairly shallow screw. The second factor is screw design. On this problem one of the raw material suppliers has done a large amount of research work, which has been published during the last two years. The screw found most efficient is a full-flighted screw with constant pitch, having a conventional compression-heating section at the feed end and a flighted metering section at the front. The flights in the metering part are very shallow, preferably below .100". This metering section extends these four flights back from the front end of the screw depending on the size of the extruder.

Due to the low viscosity of polyethylene under heat, a high amount of screening is desirable, usually down to 120 mesh size. As far as the method of heating the extrusion cylinder is concerned, electric heating has been found most satisfactory by most extruders. Now we come to die design where we have to separate the two

basic methods again. Let us discuss extrusion through a flat die first. This method has been confined almost entirely to polyethylene. It will produce polyethylene film of good uniformity which is fairly easy to handle through cooling, take-off and winding operations without too many wrinkling and distortion problems. No overhead equipment is required for this method as is needed for tubular film extrusion which we will discuss later. The most important advantage of this method is the possibility of extruding the flat film directly into a laminating station. This method has grown faster in the last few years than any other branch of the film extrusion industry. It was given a big push by the requirements of the Armed Forces for waterproof packaging, paper being used as the base material. This demand for high speed set-ups for polyethylene paper laminations has resulted in many refinements in die design, heat control, and take offs for this process.

As you can see from the photo on page 27, the type of set-up shown will give considerable flexibility in the width and gauge of sheeting which can be obtained from the same die. The amount of air injected from the bottom of the mandrel into the tube of polyethylene will determine the width of the tube. Of course, depending on whether the tube is slit on one side or both, one can end up with 36" wide film or 72" film. This points up the most important advantage of this method over flat film extrusion. One die, the initial cost of which is generally lower than for a flat die, will give a whole range of widths. The gauge of the film is determined by the speed of the overhead pull-and pinch rolls. Uniformity of gauge is of great importance to obtain an end product of uniform properties. In winding the film on a core, gauge variations will complicate matters considerably, or make it impossible to wind a roll of decent appearance which will not be distorted and wrinkled. To attack this problem, you have to visualize that the stock emerges from the extrusion die orifice at about ten or twenty times the wall thickness which is desired in the finished product. Therefore, the finished gauge is obtained entirely by stretching the tube of hot film outside the die, this stretching in width and length being accomplished by the air pressure inside the tube and the speed of the pinch or take-up rolls. It is obvious that the speed of these rolls has to be extremely uniform and subject to fine control. The other variable is the air-pressure inside the tube. You have here a closed system, the tube being terminated at the lower end by the extrusion die, through which the air is introduced and at the upper end by the pinch rolls. Therefore, if the film has no holes through which air could escape, once the bubble is brought to the desired size by introducing air, the air-flow can be shut off and the size of the bubble maintained by the entrapped amount of air. There is only one other variable to consider, and that is one causing the biggest problem in gauge control. As the stock emerges from the die, it is expanded to the desired width and gauge by the air. If one section of the die near the orifice is 5° higher than another, the stock emerging from that section will stretch much more readily than the stock emerging at a lower temperature. At the same time, the hot stock being pulled upward can easily cause an updraught on one section or side of the bubble and cool the stock before it stretches to the proper gauge and width. The stretching cycle is usually finished within three feet from the die orifice. The rest of the way to the pinch rolls can be utilized for cooling if necessary. This can be accomplished in many different ways, like fog sprays, air jets, or cooling coils. In flat film extrusion there is some stretching done between the die and the cooling bath. This distance is much shorter than the travel of the tube, but on the other hand it is easier to achieve uniform heat in a tubular round die than in a long flat one.



Fifteen inch diameter circular die with slitter knife. (Photo courtesy of National Rubber Machinery Co.)

WINDING OF FILM PRESENTS PROBLEMS

Winding presents a problem because we are dealing very often with very thin films down to .00075" of high elongation. Equipment has been built to surface wind at the pinch, riding the core at an adjustable angle against the pinchroll. This is the safest way because there is no place where wrinkles can form. I am opposed to this method because the film does not get a chance to relax and release stresses. Therefore, all shrinkage will occur after winding and distortion will result. I prefer to bring film loosely away from the pinchrolls, then remove all wrinkles which might have formed before winding. Standard textile methods can be applied here like edge-guiders, slat expanders, and tension controls.

These mechanical problems are the same whether polyethylene or P.V.C. is extruded through a circular die. Mechanically, the following additional problems have to be considered in extruding plasticized P.V.C.

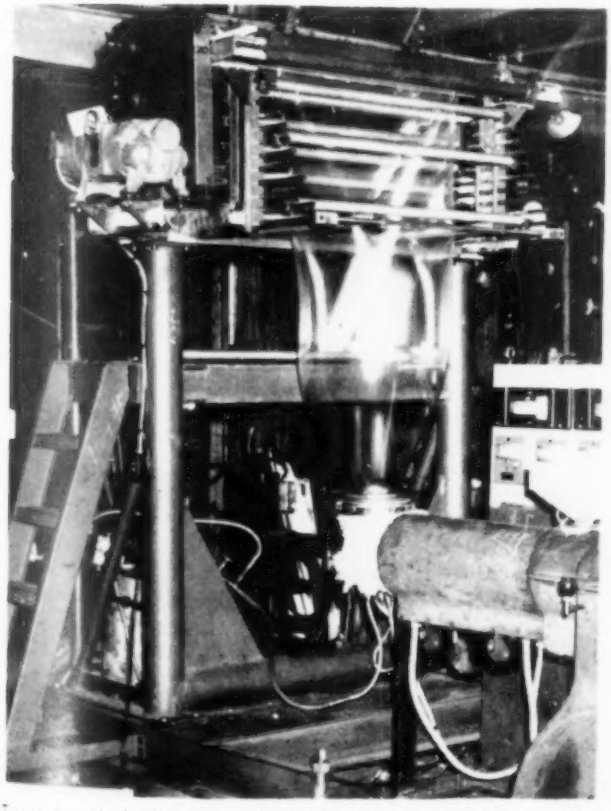
1. Proper dispersion of raw materials.

2. Heat control in the extruder barrel. Depending on the type of P.V.C. compound to be extruded considerable frictional heat is created in the barrel. This problem has to be considered in screw design. Present day experience indicates that a full flighted screw probably with constant pitch and decreasing depth is most desirable. The compression ratio will have to depend on what type of material has to be extruded, with dry blends naturally requiring higher compression ratios than granules or hot strip. The compression which can be achieved with a constant pitch screw is limited, because if we start with considerable depth in the feed section, heat transfer will be poor. Therefore, for dry blend, a variable pitch decreasing depth screw might have to be used. Besides screw design the type of heating used on the barrel is of im-

gutta-percha. Oil heat is excellent when it comes to controlling frictional overheating. On the other hand with oil heat it is very expensive to break the barrel up into a sufficient number of zones in order to control local overheating. Some present day electric heating systems in combination with well designed air or water cooling will result in more flexibility at lower cost but they do require more skill from the machine operators.

Because of the poor heat stability of P.V.C. compared to other thermoplastics, complete streamlining of the die becomes extremely important. Any crevice where material can hang up in the die under the extreme heats required for proper extrusion will cause catalytic breakdown. The other problem is created by the higher pressures needed to extrude the more viscous P.V.C. The circular film extrusion dies have a mandrel or pin supported only below the entrance channel of the material from the extruder. The material presses against the unsupported part of the mandrel which can result in deflection, which is hard to compensate. Everybody who has tried to extrude P.V.C. through this type of die is familiar with this problem. It is a real challenge to the die designers. In mentioning all these problems peculiar to P.V.C. extrusion like dispersion, frictional heat, prevention of hang-up in the die, and reduction of pressure needed to push through the die, it becomes obvious that formulation of a P.V.C. compound for this operation becomes very critical.

Without any doubt, the ideal way is to dry-blend the material and extrude directly from this dry blended powder. This is by far the cheapest and fastest method and keeps the heat history of the compound very low if done properly. For a discussion of dry blending methods, I can only refer you to the Symposium held by the Akron group last year. (Symposium on Vinyl Compounding, SPE Journal, Vol. 9, No. 11, Nov. 1953 and Vol. 9, No. 12, Dec. 1953). But keep in mind, that not every compound can be successfully extruded from dryblend. Highly plasticized compounds, compounds with high amounts of filler or hard to disperse pigments, pose real problems which might make it necessary to fuse these compounds thoroughly before they enter the extruder. The heat stability of the compound is of greatest importance. I cannot emphasize strongly enough that the success of a film extrusion operation depends primarily on the heat stability of the compound. The requirements for stability are much higher in film extrusion than in any other vinyl processing method. In evaluating systems for this process, keep in mind that all heating is done in an airfree, closed system, and therefore, stability tests should be run under similar conditions. As far as choice of plasticizers is concerned, keep in mind the proportionally high surface area of a thin film, therefore requiring plasticizers of a high order of permanence. It is desirable to choose plasticizers which will give compounds of easy flow under heat and pressure.



Twenty four inch diameter polyethylene tubing extruded from eight inch circular die. (Photo courtesy of National Rubber Machinery

CHOICE OF LUBRICANTS IS IMPORTANT

To make a P.V.C. compound process properly through the extruder and die, and to get a film which is non-blocking and clear, and which prints and heat seals without difficulty, will require a very careful choice of lubricants. The formulation of a completely clear film poses the biggest problem. Really clear films have to have a perfectly smooth and glossy surface in order to give the desired light transmission. On the other hand, the smoother the surface, the more blocking will be experienced. The proper anti-blocking agent acts by exuding to the film surface and forming a surface film which prevents sticking to the next layer. The problem is how to find something which will exude to the surface, and have a refractive index close to that of the vinyl compound in order to maintain clarity, and not interfere with ink adhesion.

My own choice is a plasticizer which has lubricating properties. This of course is dangerous because the amounts used and the processing conditions have to be very closely controlled in order to achieve exactly the proper amount of exudation. But some synthetic waxes can be used in very small amounts to aid the anti-blocking and they will help in processing. It is not possible to streamline an extrusion set-up sufficiently to prevent completely the compound from sticking in some corners. Here again proper lubrication will be helpful in reducing or even preventing the adhesion to the hot metal of the extrusion die. This problem becomes less difficult when utmost clarity is not required.

The future growth of polyethylene film usage is assured, even if we consider just the most important field of packaging, particularly of fresh fruits and vegetables. As far as vinyl film is concerned, it will be necessary to overcome some of the present processing and formulation problems, before extruded vinyl film will find its proper price level and the growth of this field is assured. But considering the progress made in the last few years, and the excellent properties which can be obtained, there is no doubt that extruded vinyl film, particularly below .0025" thickness will find a considerable volume market.

Some of our large raw material and equipment manufacturers have already recognized the large rewards waiting for the pioneers. But like all pioneering, it involves a considerable risk.

POLYESTER RESINS

and their industri

I. E. MUSKAT
Celanese Corp. of America
Marko Products Division

POLYESTER RESINS, commonly referred to as "low pressure resins" belong to a group of materials which may be defined as polymerizable thermohardened resins. These resins are distinguished from the polymerizable thermoplastic resins, such as acrylates, vinylites, and styrene, because the polymerized product is thermohardened; and they are also distinguished from the thermohardened resins, such as phenolics, ureas and melamines, because they are produced by polymerization rather than by condensation reactions and do not give off any volatile end-products and do not require pressure.

For the purpose of this discussion synthetic resins and plastic materials may be classified as follows:

I. Naturally occuring high molecular weight materials or derivatives thereof.

In this group are included cellulose and its derivatives, (nitrate, acyl esters, alkyl ethers, etc.), rubber and its derivatives (chlorinated, HCl addition product, etc), starch, rosin and the like.

II. Thermoplastic Resins

(1) Condensation reactions

Included in this group are long chain esters of dihydric alcohols and dibasic acids produced thru methathetic reactions, Nylon, etc.

(2) Polymerization reactions

In this classification are found most of the common thermoplastic resins of commerce. They may be designated by the formula A-B, in which A represents the polymerizable part of the molecule, i.e. that part of the molecule which gives rise to the property of polymerization, and B represents that part of the molecule which determines the properties of the polymerized product. In this way the chemist can, to a large extent, control the characteristics of the product he makes and thus "tailor make" the resin molecule to meet any desired requirements. A terminal vinyl group usually serves as A, and, as may be seen from the following table, nearly all commercially important thermoplastic resins are derived from this vinyl group.

Ethylene	Polyethylene, Polythene
Vinyl Chloride	Vinylites, Koroseal
Vinylidene Chloride	Saran
Methyl Acrylates	
Methyl Methacrylates	Lucite, Perspex, Plexiglas
Vinyl Acetate	Vinylites
Vinyl Butyral	Butyral
Styrene	Polystyrene

These all have in common the polymerizable vinyl group A. The properties of the polymerized plastic are determined by the Group B.

III. Thermohardening Resins

(1) Condensation reactions

Phenolics, ureas, melamines, alkyds, etc. come in this category. These resins are produced through normal methathetic condensation reactions with the evolution of volatile by-products. The condensation reaction usually is permitted to advance by means of heat to an intermediary stage in which the product is still soluble and fusible, and the condensation is then completed by means of acid or alkaline reagents.

(2) Polymerization reactions

This is the classification in which the new, so-called "polyester" or "low pressure" or "contact pressure" resins are included, and is the subject of our present discussion. These products may be designated by the formula A-B-A', in which A and A' represent the parts of the molecule which give rise to the property of polymerization and cross-polymerization (they may be the same groups or different) and B represents that part of the molecule which determines the properties of the final polymerized product. A and A' could be vinyl groups but the commercial production of polyvinyl esters is still very difficult, and therefore allyl groups have been used for introducing functionality (polymerizable unsaturation) into the molecule. A and A' may also be polymerizable unsaturated acyl groups such as acrylates, fumarates, maleates, etc.

The polyester resins of commerce are generally of two types:

1. Polyallyl esters, such as diallyl phthalate, in which the polymerizable groups are in the alkyl groups and
2. Unsaturated alkyds in which the polymerizable group—the maleic or fumaric acid groups—are in the acyl part of the molecule.

tri...pplications

There are, of course, resins in which the polymerizable groups are both in the alkyl and in the acyl parts of the molecule, such as allyl methacrylate. However, these resins are not of commercial importance at the present time. In general the unsaturated alkyds have reached larger commercial use than the corresponding allyl resins because of their faster curing, lower price and more ready availability, and because it is much simpler to work with them. The rest of the discussion will be limited to polyester resins of the unsaturated alkyd type.

UNSATURATED POLYESTERS

In order to obtain optimum properties and workable viscosities the unsaturated alkyd polyester resins must be co-polymerized with a monomeric mono-functional resin, such as styrene, vinyl acetate, or methyl methacrylate; or they may be co-polymerized with monomeric polyfunctional resins such as monomeric allyl phthalate. However, it is generally customary to use monomeric styrene as a co-polymer for the unsaturated alkyds since the over-all properties and ease of handling are considered to be superior although other comonomers are used to a limited extent. The amount of co-polymer that is used varies with different resins. In most cases 35% of styrene is used, if less styrene is used a "cheesy" product results on curing, and if more styrene is used the final product is too thermoplastic. In addition most polyester resins of commerce are not compatible beyond 35-40%, particularly on aging. However, some more recently developed polyester resins are compatible with styrene in all proportions and as little as 5-10% may be used to give thermohardened properties to styrene. These latest resins are also compatible with methyl methacrylate over the entire range and very interesting copolymerized products have been made from these co-polymers.

These resins (the unsaturated alkyds plus styrene) are liquids in which the viscosity may be varied over a considerable range—from that of water to a viscosity of that of molasses; the color can be varied almost at will and fillers can be added to produce specific properties such as high-heat resistance, fire-resistance, and toughness.

These resins can be cured by the addition of peroxides or by means of ultraviolet light. However, it is more customary to use peroxides for the control of cure.

PEROXIDE POLYMERIZATION

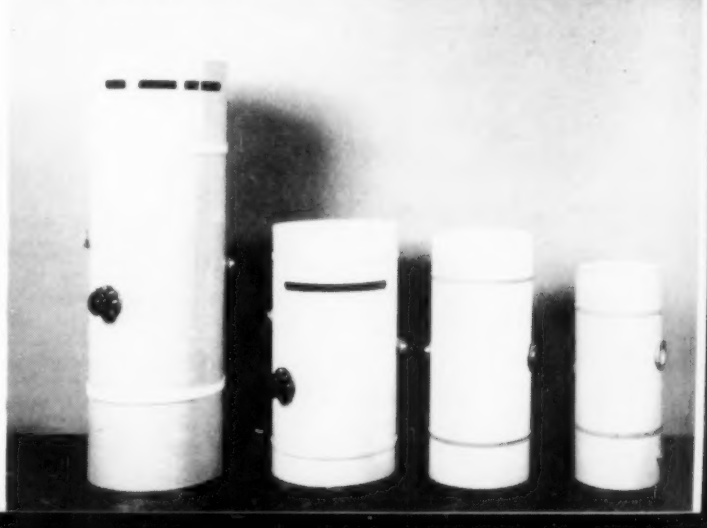
The polymerization of these resins by means of peroxides has been studied in some detail. It has been found that polymerization can be effected by means of a large

(please turn to page 44)

High frequency antenna shelters, ten feet in diameter.

Arctic sleds of polyester.

(Above) Twenty two foot inboard cruiser. (Below) Aircraft tanks for water and de-icer fluid.



THE *Injection* MOLDERSCOPE

By A. R. Morse

President, Injection Molder's Supply Co.

"It is the freedom to disagree, to quarrel with authority, in intellectual matters to think otherwise, that has made this nation what it is today." Dr. James B. Conant

GATX

One hears a great deal of talk pro and con in the trade about General American Transportation's huge venture in custom injection molding. Let me give you my impression.

First of all, under Ken Rouzer's able guidance, this plant operates on a realistic basis. In the past fifteen years, I have been in many molding rooms and one soon can "feel" whether a plant is producing economically or just churning its wheels. At GATX I got the "feel" that here was a plant being run as a good competitive custom molding shop should be run. Engineering under Harry Bennett also was under a firm hand. One gets an impression of team work and competently delegated authority on a production level here that smaller plants could well emulate.

The range of presses runs from 2 to 300 ounces as everyone knows, with heavy emphasis on BIG presses. The equipment is capably maintained. When you see the size of a 300 ounce press, you realize what maintenance can mean, and you have to reset your sights on upkeep costs. It is a staggering experience to visit one of the world's largest injection plants (as I would rate the vast Parrish Street Plant of the GATX Plastic Division) even without considering it (as I do) from the angle of maintenance and production.

The most successful way of handling hot thermoplastics it seems is NOT to fight leakage at valves and around the plunger, but to let the hot material act as an actual lubricant. Some amount of leakage flushes out leak-back material that might otherwise mark the plastic by being dragged forward into the storage chamber. You cannot question that huge strides in preplasticizing have been made. But many problems remain.

Contamination, part making, burning, cold spots, all contribute to molding defective parts. Undoubtedly strains are less, partial fills and flash as a cause of rejects are less, but preplasticizing, while it eliminates some causes of part rejection, probably contributes some new ones of a somewhat different nature. Preplasticizing is no cure-all.

CLAMP AND PREPLASTICIZERS

An outstanding molder, who probably knows as much about thin section work as anyone, brings up a neglected injection machine specification that ties in with the lowered clamp argument. He says that what counts in a press is its ability to shove hot plastic between cold steel. His own private formula for this is based on existing plunger speeds. This vital specification could be considerably increased if plunger speeds could be increased. You still need just as much clamp as with a conventional cylinder. This is quite a new idea in machine specifications—and one that is going to have a profound effect on injection machine design once its importance to our industry is clearly understood.

Suffice to say, preplasticizing today requires just as much clamp as standard molding. If injection plunger speeds were increased a great deal more work could be done on existing equipment of both standard and preplasticizing types. We will all do well to begin to correct our impressions of the miracles to be wrought by preplasticizing in the way of reduced clamp and pressure requirements.

AND KEL-F

Actually I did not visit GATX to write about it but to see how our extra-capacity heating cylinders were doing. It was a pleasant surprise to learn that they would do a tough Kel-F job. We can all learn something from the way Kel-F molds. It resists melting until it is very hot, then almost instantly, it fuses and heat control is extremely critical just at this point. If a cylinder is designed for Kel-F, it will do wonders with high impact styrene as you don't have such a close breakdown point. The area of extremely critical control on Kel-F is only about 1". On high impact, it may run from 3" to 4" horizontally on the heater.

Extremely sensitive tests can detect a falling off in properties of Kel-F if it is incorrectly melted in a heater, so look for Kel-F to teach us a lot about cylinder design that we can't pick up even on high impact styrene.

I continue to collect evidence that Kel-F and high impact styrene copolymers require extra care in molding. Indeed, I believe internal modifications should be made in all heaters to take account of variations in molding characteristics of the various types of plastics. We recommend this where a heater is going to mold say Kel-F or vinyl only. A general purpose cylinder is good but a special purpose one can out-perform it and outlast it. We aren't specialized enough yet, but the day is not too far off when you'll see heaters reserved exclusively for one type of thermoplastic. And believe it or not, we are already making a few heaters which are specially modified to handle a given material!

New Inexpensive Presses for Reinforced Plastic Molding

A new type of low pressure press for molding reinforced plastic is being offered by Davidson-Kennedy Company, Atlanta, manufacturers of hydraulic presses for more than 65 years. The design was developed in cooperation with engineers of Gladwin Plastics Company.

New in operational design, these presses utilize air cylinder pressure for 90% of the platen or die travel and a self contained hydraulic unit furnishes power for the pressure stroke. They are fabricated from structural steel, welded and stress relieved, and are readily movable, requiring only air line connections and electricity for control units. Stroke, daylight openings and pressures can be furnished in a wide variety of combinations.

Simplicity of design makes it possible to market the presses at exceptionally low cost. In addition, it has unusual adpatability and presses can be made to the specific requirements of a particular die.

The new presses have been thoroughly plant tested and a number of models are presently being used on production operations.

New Lead Screw Tapping Head fits any Drill Press.

A new, complete lead screw tapping head that enables unskilled help to produce precision threads on any drill press has been announced by Automatic Methods, Inc., Elizabeth, N. J.

The new AUTO-TAP HEAD features a rapidly interchangeable lead screw, a new type cone clutch reversing mechanism, and postive depth control to assure perfect threads even in blind or recessed holes.

Two Auto-tap Head models are available for tapping #0 to 5-16 and #10-32 to 3-4" threads. The manufacturer, Automatic Methods, Inc., 965 W. Grand St., Div. 192, Elizabeth, N. J., will send details and prices upon request.

AROUND THE WORLD

BELGIUM

MATIERES PLASTIQUES ET RESINES SYNTHETIQUES

No. 67, Nov.-Dec. 1953

Abstracter: A. P. Daignault

HYDROGENATION OF COAL (Page 9)

A short summary of the methods used by the Union Carbide & Carbon Co. in hydrogenation of coal on an industrial scale and the results obtained. It compares the importance of this process to the chemical industry to that of catalytic cracking in the petroleum industry.

A NEW TRANSPARENT SURFACE COATING FOR WOOD FINISHING (Page 11)

A description of a cellulose-acetate-butyrate and EAB-381 coating as reported at the 122nd convention of the ACS by Mr. Fred Ball and Mr. William Gearhart of the Tennessee Eastman Co. The new coating which can be applied by dipping, by brush, or by spraying gives a finish with greater resistance to yellowing and cracking, as well as a greater resistance to fire. This material has high flexibility and excellent adhesion making it suitable for use on bowling pins, croquet balls and tool handles. Like other coatings this material requires a primer coat.

VACUUM FORMING by E. B. Stratton, Jr. (Page 12)

Translation of paper presented at ninth SPE Conference and appearing in SPE Journal, Volume 9, No. 4, April 1953 (Page 24).

NEWS OF THE WORLD (Page 15)

A series of briefs on new plastic materials and applications, including:

(1) Utilization of Dielectric Properties of Synthetic Resins.

(2) New Uses for Glass Fibers.

(3) Utilization of Thermo-Indicator Paints.

(4) New transparent packaging material.

(5) New Plastic Tank Truck.

PICTURES OF VARIOUS PLASTIC APPLICATIONS (Page 20)

(1) Cadillac with reinforced polyester body.

(2) Reinforced plastic boats.

(3) Vinyl plastisol sponges.

(4) Pad holder and tumblers of styrene.

(5) Laminated furniture.

(6) PVC protective garments.

GERMANY

KUNSTSTOFFE

Vol. 44, No. 1, January 1954

PROCESSING OF POLYAMIDES ON THE EXTRUDER. By Ir. J. F. Kohlwey

The characteristic processing properties of polyamides are considered; this is followed by an examination of the functional elements of the extruder with regard to their requirements and working methods. The high shear action of polyamides demands a special hopper design. The worm must be divided into preheating, melting and pressure zones. What happens in these zones is discussed both from the practical point of view and on the basis of mathematical theory. This contribution—which is based on practical experience—closes with hints on the heating and design of dies.

RAW MATERIAL PROBLEMS IN THE SYNTHESIS OF PLASTICS. By Helmut Meis

A few examples show the line of development of the raw materials supply for plastics synthesis. The first source was coal tar, where quantities of phenol, additional to that occurring naturally, were produced synthetically. This was followed by acetylene forming the basis for vinyl compounds. Lastly, petroleum byproducts are serving increasingly as chemical raw materials.

ALPHA - CHLORO - ACRYLATES. By Klaus Tessmar

Possibilities in acrylic resin chemistry are shown which permit the production of "tailor-made" plastics by substitution and copolymerization. The characteristics which are aimed at for the technical application of such special types are improved hardness, tensile and flexural strength, improved dimensional stability under heat and wide variation of optical properties.

THE RIGHT TECHNICAL TERM. By E. Mollberg

A contribution to the discussion on "Injection Molding" v. "Pressure-Casting."

INJECTION MOLDING COMPOUNDS FOR BATTERIES. By Werner Laeis

After initial difficulties especially polystyrene and polyamide injection molding compounds are being used for cases, plugs, separators and other ancillary equipment. Development and the present state are reported.

TOOL DESIGN FOR INJECTION MOLDING MACHINES COOLING OF TOOLS. By Hans Gastrow

In previous contributions the choice of a suitable material for the tool and the ejection of molded parts was described. In the following design details with regard to the cooling of tools are discussed.

VACUUM MOLDING OF THERMOPLASTICS SHEET AND FILM.

Apart from the deep drawing press, plastics plates and films have hitherto mainly been molded by the blowing method. The vacuum method, developed in U. S. A., is being introduced only slowly over here. The following is a description of an automatic equipment, which has been developed for the European market for the deep drawing and vacuum molding of rigid and soft thermoplastics sheets.

EXTRUDING POLYSTYRENE I. THE CHARACTERISTICS OF SUITABLE EXTRUDERS.

The extrusion of polystyrene was until recently an unsolved problem; existing difficulties could be overcome only lately. Extensive experimentation created the basis for routine economical production of even complicated profiles. This has opened new ways for the production of refrigerator parts, lighting equipment, rods, tubes, films, bristles and profiles for decorative purposes.

We are considering here the characteristics of suitable extruders; a second article will deal with method, and more especially the design of tools.

★

GREAT BRITAIN

BRITISH PLASTICS Vol. 26, No. 294 Nov. 1953

Abstracter: E. A. J. Mol

TRENDS IN EXTRUSION MACHINERY, pp. 392-399. By E. D. Fisher

In this article, the author, formerly with Windsor Ltd, now a technical consultant in extrusion, gives a survey of recent developments in screws, barrels, adaptors and drive units.

No new theories are advanced on screw design but the more important trends are mentioned concerning:

(1) Length diameter ratio; (2) Compression ratio; (3) Type; (4) Mechanical perfection; (5) Temperature; (6) Speed.

After a short discussion of the two stage or extraction screw, sometimes constructed as a dual diameter screw with adjustable valving arrangement, attention is paid to the intermeshing multi screw. Here the advantage is the positive forward movement, as the screws constitute a special form of gear pump.

There are two general types and their difference is in the relative direction of rotation of the screws. The two possibilities are (a) Rotation is in the same direction, the action is that of drag flow without back flow, heat build-up takes place but is not very large as rotational speeds are low. Usually the screws have three separate zones of different diameter and pitch. This is the type made by Windsor Ltd. (b) Rotation is in opposite directions. Little shear or drag flow, less heat build-up. The Mapre-machine uses deep-cut square thread type screws, compression is obtained by means of gradually decreasing clearance between the flanks. No water cooling on the screws. The Trudex construction has completely intermeshing screws and both are water cooled. No compression of conventional form is attempted.

In both machines, the escape of entrapped air is a problem, usually solved by notching the final threads of each screw. Both the Mapre and the Trudex machines are equipped with vapor extraction systems for which this type of an extruder is especially suitable.

A very interesting new development is the Pasquelli bihelicoidal system, using three pairs of intermeshing helical gears of decreasing diametral pitch, running in a housing of a special form.

The heat control on the barrel is discussed in some detail, temperature differentials at barrel and screw and the frictional heat developed in the plastic are taken into consideration. Various heating and control systems are discussed, electrical heat is compared against steam and oil heating.

In barrel design, place and form of the feed port is considered, the modern trend is a radial entry circular feed port, often chromium plated.

The die adaptor, holding breaker plate and screens, must allow for rigid and leak proof attachment of a large variety of extrusion dies. Various designs are in use, simple screwed in or bolted on connections, collet nuts, bayonet fittings, wedge-locking split clamps and hinged heads all have their place.

A discussion of the drive unit concludes the article. The trend is to larger outputs at higher screw speeds, this can only be achieved when the drive can supply considerable extra power and the thrust arrangements can withstand the extra pressures involved. Furthermore, for flexible operation the drive must be of the continuously variable type.

MOLDS AND STRESSES, pp 402-406. By G. Stimpson

The author considers the effect of mold designs upon the residual stresses in injection molding, the stresses introduced during ejection of the molding from the mold are probably the most important. These ejection stresses are caused by a distortion due to, for instance, a sticking sprue or inadequate support for the molding. Anchoring, stripper plates and special gate arrangements are advised together with slow mold parting and slow ejection devices.

The design and the location of the gate are also important, especially as pin-point or restricted gating is rapidly gaining in popularity. The gate velocity is a determining factor, "jetting" must be avoided.

Mold finish and mold temperature need careful attention. Rough spots or proud ejector pins cause flow retardations and stress concentrations. The same holds for temperature differences even when the overall temperature is in the correct range.

In the molded article itself, sharp corners and restrictions should be avoided, reinforcing ribs are an additional hazard in causing extra weld lines and stress concentrations.

As to the detection of stresses, the author states that the most convenient and efficient method for polystyrene articles is immersion of the moldings in white spirit for 10 minutes at room temperature after which the molding is allowed to stand for a few hours. Stress concentrations manifest themselves in cracking and crazing, the type of cracking often allows a close guess as to the cause of the stresses.

ILLUSTRATED GUIDE TO PLANT AND EQUIPMENT, pp 407-440. Anon.

Briefly describes Injection molding machines, Compression presses, Extrusion machinery, Pelleters, Tabletters, Preformers, Heating equipment, Welding equipment, Mixers, Blenders, Grinders, Granulators, Cutters, Process controllers and miscellaneous accessories.

DEVELOPMENTS IN MOLDING EQUIPMENT, pp 388-391. Anon.

There has been a trend to replace large machines by relatively small ones with a correspondingly lower number of cavities, equipped with controls for fully automatic work. At least five machine builders in Britain now offer such machines (Daniels, Dowding and Doll, Herbert/Reed-Prentice, Projectile and Windsor).

For large machines, preplasticizers have been introduced to improve the plasticizing capacity and efficiency. A rather unusual conception is the new Windsor single stage, multi - screw pre-plasticizer. The plunger consists of two intermeshing screws that can slide forward and backward in the barrel.

It has been generally recognized that accurate mold temperature control is of the utmost importance for best results in molding, especially for more intricate moldings. Projectile has developed a mold temperature control unit using water as the heat transfer medium.

In the thermosetting field also the trend is to automatic molding. Special cycle control units, as for instance the Daniels timer and the Autodraulic push button control system of Towler Bros. are now on the market. For glass-reinforced moldings special low pressure presses have been developed by Daniels (100 tons, 48 in. X 36 in. table area) and B.I.P.-Engineering (10-50 tons, 48 in. X 48 in. table area).

MODIFYING TEMPERATURE DISTRIBUTION OVER CALENDER ROLLS BY ELECTRO-MAGNETIC INDUCTION, pp 400-401. By G. Ardichvili

It is difficult to keep the surface temperature of calender rolls exactly the same over the entire width of the rolls. In most cases the temperature drops near the ends of the rolls, thereby severely restricting the useful width.

Furthermore, uneven temperatures result in unequal diameters of the rolls, this is a chief difficulty in the production of thin gage film. By making the roll wall part of a magnetic circuit, heat can be generated right in

the roll wall by electromagnetic induction.

The induction coils can be placed anywhere along the rolls without obstructing the movement of the plastic as no contact between coils and rolls is made. When one coil is placed at either end of the calender roll a practically flat temperature distribution over the entire width of the roll can be achieved, thus greatly increasing the efficiency of the calendering operation.

NEW DEEP DRAWING MACHINE. pp 441-443. Anon.

Description of the Formvac machine, developed by the Plastics Research and Development Division of Hydro Chemie Ltd., Zurich.

This machine performs precision vacuum forming with inexpensive molds continuously and almost completely automatically. Moldings of any size up to 24 x 36 in. and 6½ in. depth can be formed from flexible and rigid sheets. Heater times and temperatures are preset, the radiant heat unit slides back and forth on rails over two mold plates it serves.

BRITISH PLASTICS Vol. 26, No. 295, Dec. 1953

MANUFACTURE OF BUS PANELS IN GLASS-POLYESTER, pp 450-452. Anon.

Curved aluminum panels on buses are replaced by molded glass-polyester sections. The plastic panels are lighter (saving gasoline) and cheaper to make. A short description of the actual fabrication technique is given revealing no new information.

MOLDINGS FROM FIBRE-RESIN PREFORMS, pp. 453-456. Anon.

This is a description of the fabrication of fibre reinforced articles in a low cost process. The fibre (cotton waste and rag) or even the pulp, is either mixed with a resin dispersion in a kind of mull or before preforming or impregnated with a resin solution after preforming.

The preform is made in the usual way by suction on a felting tool, made of perforated metal covered with a wire screen.

The final curing is in most cases done on a low pressure press, the molding time depends on the amount of resin in the felt and lies between a few seconds and a few minutes. Although Urea-formaldehyde, melamine and vinyl resins are also used, modified phenol-formaldehyde resins are actually used in the examples described.

THE SILVERING OF PLASTICS, pp 457-460. By K. S. Low

The process is that of chemically deposited silver as contrasted to electro-plating or vacuum deposition. It is basically cheaper than the other techniques but requires more care in operation.

The surface to be coated must be perfectly smooth, usually this is obtained by first applying a thin coating of a suitable lacquer. For mechanical protection the silver layer has to be covered with a transparent lacquer.

The metallic silver is produced by reducing a slightly alkaline ammoniacal silver nitrate solution with a sugar or formaldehyde solution after sensitizing the plastic surface with a hydrochloric solution of stannous chloride.

Best effects are achieved by spraying on both solutions separately from a double barreled spray gun, the object is placed approximately at a position at the point of impingement of the two jets.

The following cycle of operations is used in actual processing:

(1) Cleaning and degreasing with subsequent drying, if necessary; (2) Application of undercoat; (3) Drying or setting of undercoat; (4) Sensitizing; (5) Washing; (6) Silvering; (7) Washing; (8) Drying; (9) Application of top coat; (10) Drying or setting of top coat.

The process can be adapted to silver glass easily, installation costs are very low.

EXTRUDED RUBBER - MODIFIED POLYSTYRENE SHEET, pp 462-464. Anon.

Essentially a description of the properties and forming techniques of Campco S-300, manufactured by the Campco division of Chicago Molded Products Corp.

BEHAVIOUR OF POLYTHENE IN THE TROPICS, p 473. Anon.

This is a report on work carried out in Nigeria. Tested were Alkathene 7 and Alkathene 20, both incorporating 0.1% of anti-oxidant, with or without 0.1% of Carbon Black. The climatic conditions were:

Jungle undergrowth, jungle clearing, semi-desert and tropical surf beach.

There was no difference between the two grades but the Carbon Black provides a considerable measure of protection.

Unprotected material has a useful life of six months or less in the desert, less than a year on the surf beach and about a year in the jungle clearing.

The report further says:

Polythene is resistant to the moisture of tropical climate as represented mainly by the jungle exposure sites, but is susceptible to the actinic effects of the tropical sun, preponderant on the beach and desert exposure sites. These effects are greatly reduced by Carbon Black which is specifically recommended for this purpose by the makers of polythene. The main results of continued sun exposure are: an increase in brittleness, exemplified by loss of flexibility and extensibility, a rise in cold bend temperature and the appearance of surface cracks, a thirty-fold rise of power factor in the absence of Carbon Black and a tenfold rise in the presence of Carbon Black, under the worst conditions of the trials described.

Ductility and low power factor are the foremost properties leading to the selection of polythene in preference to any other material. It would be necessary, therefore, either to be satisfied with limited service life in direct sunlight or to provide additional protection for the material.

BRITISH PLASTICS

Vol. 27, No. 296, Jan. 1953

LARGE POLYSTYRENE MOLDINGS FOR INDUSTRY, pp 6-11. Anon.

Radio, television and refrigeration are using increasing quantities of larger and larger moldings.

Examples:

Breaker frame, 25 in. x 30 in., weight 26 oz., produced on 48 oz. machine, nine shots per hour.

Crisper cover, 18 3 16 in. x 11 11 16 in. x 1¼ in., weight 24 oz., 17 shots h. oil heated mold.

Crisper tray, 18½ in. x 12 in., x 6½ in., weight 32 oz., produced on a 16 oz machine with extra capacity cylinder.

Evaporator door, 18½ in. x 8½ in. x 1⅜ in., weight 15 oz., produced on a 16 oz. machine.

Refrigerator drawer, 14 in. x 10¾ in. x 5 in., weight 22-24 oz., produced at a rate of 35-40 per hour on a 16 oz. machine.

Radio grille, 15½ in. x 10½ in., weight 16 oz., produced on a 16 oz. machine at a rate of 45 per hour.

Cathode ray tube masks, 18 in. x 16 in. x 2 in., weight 32 oz., produced on a 48 oz. machine at a rate of 15 per hour.

The greater part is molded in standard medium impact polystyrene, high impact polystyrene requires higher cylinder temperatures. Jigs are often used to prevent distortion after ejection during the cooling to room temperature, annealing is not so widely used as it deserves for reasons of economy. The question of scrap is a very important one, it is often advantageous to mold at a slower rate to minimize rejects.

PVC-EXTRUSIONS IN TERRAZZO FLOORS, pp 16-17. Anon

The dividing strips laid in terrazzo floors must have the same hardwearing properties as the floor. Not worse, but not better either as in the latter case, the strip will project above the floor level after the terrazzo has become worn down.

Special grades of PVC have the desired wearing qualities. Patterns are easier to obtain than straight lines as the PVC strips have a tendency to bend and twist. An advantage is the wide color range in which the strip can be manufactured.

INEXPENSIVE VACUUM FORMING OF SHEET THERMOPLASTICS, pp 18-19. Anon

Another inexpensive realization of the well known vacuum forming method, this time developed by British Celanese. Capital investment is low, even for large scale production expenditure will not be over 200 pounds sterling.

NYLON CATCH TO LAST 100 YEARS, pp 22. Anon

Nylon catches, replacing steel ones in kitchen cabinets, have been tested for failure in a machine, simulating as closely as possible the normal use of a cabinet door.

The nose of the metal catch failed after a run equivalent to about 10 years' actual use, the nylon catch was exhibiting no apparent wear after 100 years' use. Furthermore, nylon catches do not rust as their metal counterparts do.

200 OZ. INJECTION MACHINE, p 32-33. Anon

A description of the model 1200-P-200, a 200 oz. preplasticizing injection molding machine, announced by The Hydraulic Press Mfg. Co. of Mount Gilead, Ohio.

PLASTICS MATERIAL SALES INCREASING, pp 1-5. Anon

This is an interesting article, giving facts and figures of Plastics Sales in the United Kingdom for 1953.

From it we learn that the total plastics production in the U.K. is estimated to be 185,000 tons, a figure surpassed by Germany with 225,000 tons. Starting from practically zero in 1946, the Germans have made a tremendous effort to regain the lead in the plastics industry in Europe, since 1951 they have succeeded in that goal.

About 30% of the U.K. sales are exports, the biggest slice of this has gone to Australia. Export has become increasingly more difficult because of currency regulations and because of more polymer plants going up in overseas' countries. On the whole, the exports outlook is fair.

Outstanding progress has been made in the Vinyl field, total production is in the region of 40-45,000 tons. Sheeting output has increased, prejudice against PVC rainwear has at last been broken down. Important too is the systematic introduction of fire resistant conveyor belting by the Coal Board. Some 10 mill. ft. are installed annually, 10% of this is expected to be in PVC.

Phenolics are still sliding down, the Aminoplasts recovered to the good position they held before the 1952 recession.

Polythene sales are steadily increasing, the production cannot keep up with demand, exports show a big backlog.

Polystyrene production totals 18,000 tons, production is increasing, more manufacturers entering the field. About 10,000 tons are exported, Australia being the biggest single customer. This will change when the polymer producing plant now under construction in Australia comes into operation.

Cellulose acetate molding powders have almost recovered from the disastrous recession in 1952 when the sales dropped from 6,600 tons to 3,200 tons. Exports have improved.

A new plant for Polytetrafluoroethylene came into operation to replace the plant destroyed in 1950 by an explosion. For the first time in three years, PTFE is freely available.

Acrylics found renewed interest with molders, particularly in the new grades for high temperatures and high humidity (for car rear lights). In the reinforced plastics field an interesting fact is that, while there is a sufficient resin capacity to cover a greatly expanded production (as in car bodies), the glass fibre supply is far below the estimated demand.

TRANSACTIONS OF THE PLASTICS INSTITUTE (London)

Vol. 21, No. 46, (1953)

Abstracter: Harriman H. Dash

RECENT TRENDS IN AMINOPLASTICS, pp. 5-26. By F. L. Hudson

The rise of aminoplastics is illustrated by U. S. production figures for 1931 (600,000 lbs.) as compared to 1951 (over 200 million lbs.). An end use breakdown of the figures for 1951 is presented in tabular form, the largest percentage going to molding powders, with adhesives a close runner-up. Experimental data is presented to show that the melamine molding powders are considerably more water resistant than ureas. This water resistance is related to staining resistance, so very important to tableware products. A Rhodamine B test is cited for proving out proper cures of melamine. Recent developments in melamines are described—use of benzoguanamines for improved staining resistance; monocresyl glyceryl ether plasticizers for improved dielectric strength, after shrinkage, and heat resistance; use of glass fibre fillers for improved strength. The use of the ether plasticizers have also been extended to ureas. Improved translucency of ureas has been obtained by use of bleached keratin or regenerated cellulose fillers and sulfonated castor oil lubricant. Mixed urea-thiourea and urea-melamine resins as stable aqueous solutions are employed in the production of laminates. New uses for ureas are as adhesives in the production of construction chip board, in shell molding processes for metal casting, and as foamed resins for low temperature insulation. The latter has a density of 0.9 lbs. cu. ft. compared to equivalent cork insulation with a density of 10-20 lbs. cu. ft. Alkylated amino-resins are employed in high gloss stoving enamels. When mixed with epoxy resins, these give hardened films with excellent flexibility, adhesion, and chemical resistance. Detailed descriptions are presented of the use of amino-resins in textile finishing and paper treatment, particularly for increased wet strength.

THE USE OF POLYVINYLCHLORIDE IN THE CHEMICAL INDUSTRY, pp. 27-45. By F. F. Jaray

The physical and chemical properties of rigid vinyl render it useful as a constructional material. However such characteristics as elastic memory (recovery of deformation), time dependence under stress, and notch sensitivity must be fully understood and taken into account when designing with PVCl. The mechanical behavior of polyvinylchloride is very dependent upon temperature. In the plastic temperature range the secondary valence forces binding the molecules is negligible or very small, and hence the material can be shaped with ease. On cooling the binding forces bring the material into an elastic state. The ultimate strength of rigid PVCl may be considerably less than its short time strength. Thus, although the material may resist a certain stress for a short time period this same stress if allowed to remain may in time crack the part since the ultimate strength may have been exceeded. If parts are greatly deformed during plastic shaping, excessive stresses may be set up on cooling. In designing with PVCl stress con-

(please turn to page 39)

SECTION NEWS

Edited by

Stanley Bindman

Jamison Plastic Corp.
71 E. Sunrise Highway
Freeport, New York

Prehardened Mold Steels for the Plastics Industry And Their Uses are Described to New York Section

A. M. Merrill

A talk on "Prehardened Mold Steels for the Plastics Industry" by Birger L. Johnson, Jr., chief research metallurgist of Latrobe Steel Co., featured the February 17 dinner meeting of the New York Section. Some 85 members and guests attended the meeting which was held in the Gotham Hotel, and also included a showing of the IBM sound-color film on electronic calculators, "Piercing the Unknown." The film was introduced by J. F. Collins, of IBM, who also answered questions from the floor.

Mr. Johnson began his talk with a brief review of the different types of mold steels available to the plastics industry. These steels are of three classes: (1) low carbon, low alloy hobbing steels; (2) carburizing, oil hardening, and air hardening alloy steels for molds which are heat treated after machining; and (3) oil hardening and precipitation hardening steels which are hardened prior to the machining of mold cavities. This third class, the prehardened steels, are represented by AISI 4130 and 6145 for the oil hardening type, and by nickel-aluminum steel for the precipitation hardening type.

Using slides as illustrations, the speaker discussed the properties and applications of the three classes of mold steels. It was pointed out that the precipitation hardening nickel-aluminum steel shows maximum hardness throughout its cross-section; can be polished readily to a very high luster because of its microstructure; gives weldings which can be machined and polished like the rest of the mold; and lends itself to nitriding.

Prehardened steels have found their most extensive application in the plastics industry in injection molds, Mr. Johnson said. Their application in compression and transfer molds has been limited so far, but should increase as more experience is gained in their use. It is apparent that the potential usefulness of prehardened mold steels for plastics has only begun to be realized, the speaker concluded.

Section president Harold H. Schwartz, Empire Brushes, Inc., presided over the business session which preceded the talk and film showing. A period of silence was observed in memory of Sidney Zweier, late of Ideal Plastics Co. & Victor Zuger of Plasticware whose recent deaths came as a blow to their many friends in the Section.

Table favors were distributed through the courtesy of Ferro Corp. and Leaf Plastics, Inc., and the meeting closed with a drawing for door prizes contributed by R. C. Molding, Inc., and Star Plastics Co. The prize-winners were Lorenz Alt, Victor Kellering Co.; Maurice Diamond, FR Corp.; and H. S. Dudley, American Cyanamid Co.

A total of 18 new members has been added by the New York Section during the past month. These new members are: Joseph J. Ashton, Vanton Pump & Equipment Corp.; Fred Bellin, Leaf Plastics; Franklin Dick, Anchor Plastics Co.; Alexander Eisemann, Jr., General Mold Casting Corp.; David W. Fisherman, New York Merchandise Co., Inc.; Joel Frados, "Modern Plastics"; Peter Gasperini, Vanton Pump; Samuel Hall, Plastic-Ware, Inc.; Ralph E. Koester, B. F. Goodrich Chemical Co.; Gerald Lewis, Vanton Pump; Edward A. Margus, Vanton Pump; John S. McBride, Owens-Corning Fiberglas Corp.; Arthur L. Metzger, A. Bamberger Corp.; Sidney Orenstein, Ablon Finishes, Inc.; Francis J. Prescott, Chas. Pfizer & Co.; David S. Sheridan, National Catheter & Instrument Co.; Sol I. Smithline, Pittsburgh Plastics Corp.; and Emile J. E. Van Dyck, Textiglass Division of Cheney Bros.

Fast Mold Repair Is Discussed at Meeting Of Southeast Ohio Section

William J. Stranathan

Approximately thirty members and guests attended the January 21st meeting of the SPE in Cambridge, Ohio. The speaker of the evening was Woodward W. Shakelford who is regional manager for the Eutectic Welding Alloys Corp. The subject covered by Mr. Shakelford was the value of having fast efficient repair at your fingertips for the repair of plastic dies so that valuable production time would not be lost in machining new dies or their component parts. He stressed mostly that the welding be done to Eutectic specifications in order that an efficient bond or weld be accomplished. He stated that with these low temperature welding alloys either gas or electric welding could be accomplished without losing the hardness or the temper of the part being welded.

Mr. Shakelford's address on efficient welding with Eutectic was concluded with the use of slides which illustrated very fully the time and money saving techniques of low temperature welding.

A discussion period followed the very interesting talk on welding.

A turkey dinner and business meeting preceded the technical meeting, in charge of President, Paul Smith, Cambridge Tool and Die Co.

New officers for the year were announced after being elected at a preceding meeting of the council. President, John Chomicz, General Electric Co., Coshocton, Vice-Pres., Paul Brill, Cambridge Panelite, Cambridge, Secretary, Charles Field, Shelmar Bettner Corp., Zanesville, Treas., Fred Burkhart, Fabri-Form Co., Byesville, Ohio. Jack Knight, Fabri-Form Co. will represent the section as National Director. Congratulations, new officers for '54 and thanks to the retiring officers for their untiring efforts in the preceding year.

Milwaukee Section Interested by Presentation Of Details of Chevrolet Corvette Manufacture

Marvin C. Stowe

The February 9, 1954 Dinner-meeting of the Milwaukee section of Society of Plastics Engineers featured Mr. George C. Aitken and Mr. Ken Mount along with Mr. Edward Hood from Chevrolet-Central Office, Division of General Motors. Also Mr. George Hammond, Coordinating Engineer from the Owens Corning Co. They have all played a big part in the development of the Chevrolet Corvette.

Mr. Aitken is Assistant Staff Engineer in Charge of Drafting at the Chevrolet-Central Office. Mr. Ken Mount and Mr. Edward Hood are also in the Engineering Department in Detroit, Michigan.

The meeting was opened with a introductory speech by our President Mr. George Stein, A. O. Smith Corp., Milwaukee, Wisconsin. Mr. Stein announced that our charter was received by Mr. Frank Bailey of Continental Can co., at the Toronto National Convention in January. Mr. Bailey is the Milwaukee section Secretary. The regular business meeting to be omitted, without further adieu Mr. Stein then introduced Mr. George Hammond who spoke on the Fiber-Glass Plastic in general being somewhat specific about the re-inforced plastic used in the Chevrolet Corvette. Mr. Hammond informed us on the development of Fiber-Glass Plastic. He brought out that the strength of the glass fibers and the flexibility of plastic along with the molding possibilities of plastic makes the perfect combination to fill the requisites of a automobile body.

After listening to a very enlightening speech on the material itself we then had the pleasure of hearing from Mr. George Aitken, Assisted by Mr. Ken Mount and Mr. Edward Hood. Mr. Aitken very thoroughly covered the molding, action, and assembly of the Corvette. They had very colorful and educational slides to illustrate both the molding and assembly. Included in the speech we were explained and shown on the slides of the various tests, experiments and researches that took place in perfecting the material and in the designing of the body.

The inception of the Corvette began with just the idea in about June 1952. By January 1953 and in time for the General Motors Auto Show in New York, the Chevrolet Division had a finished model of the Corvette on display. During the year 1953 three hundred Corvette automobiles were completed. The year 1954 will probably see 10,000 Corvettes come off the assembly lines.

G. C. Aitken

After the speeches and slides etc. were completed the opportunity of asking questions was offered the audience. Mr. Aitken, Mr. Mount, Mr. Hood and Mr. Hammond were kept busy for some time doing a fine job of answering all questions presented. After learning of all the research and development it took to perfect and manufacture this Corvette I was curious about what might be the price of this sport car. Figuring others might also be curious I can say that the Corvette costs $3250 F.O.B. Plant, St. Louis. At the present time General Motors are producing the Corvette at a loss. The breakeven point is about 10,000 cars.

Also after the meeting as well as before the meeting began, the members and guests had the privilege of inspecting all the component parts of the Chevrolet Corvette which were on display. The A. O. Smith Corp. had their complete assembly of the Corvette available for inspection also.

A complete copy of Mr. Aitkens speech on the Corvette Fiber-Glass Plastic Body can be obtained by mailing your request to: The Corvette Plastic Body, 29 W. 39th Street, New York 18, New York. Ask for speech No. SAE #212 by E. J. Premo. Anyone interested would find the speech very educational.

Yes, from an idea to the blue print, to the hardwood mahogany models, to the metal dies, to the Fiber-Glass Plastic parts, to the complete assembly is just one more way that Plastic has shown the world its usefulness and superiority.

Thanks to Mr. George Stein, his Co-Officers of the Milwaukee Section and Mr. George C. Aitken, Mr. Ken Mount, Mr. Edward Hood, from Chevrolet Division of General Motors and Mr. George Hammond from Owens Corning Co. for a very splendid evening that was enjoyed by 250 very well satisfied and enlightened members and guests.

Hays Manufacturing Company To Expand

Paul C. Roche

THE HAYS Manufacturing Co. of Erie, Pa., will enter the fiberglass reinforced sheeting and molded plastics field in the next several months at its Albion, Pa. plant, with a view to eventual large scale diversification of its products.

J. D. Clemens, vice-president and general manager, disclosed the Albion plant is now the site of the firm's curb box production.

Clemens said that "We are using about 5,000 square feet of floor space at the Albion plant for the installation of machines to make sheeting and molded plastics."

Clemens revealed the plastics operation—entirely a new field for the firm which manufactures equipment for the plumbing industry—will eventually be expanded on a larger scale.

The sheeting and molded plastics will be marketed to appliance producers and other kindred firms in the home furnishings manufacturing field.

Hays, however, will continue manufacture of its regular line of plumbing equipment, which includes a wide variety of underground fittings for water departments and gas companies, valves for electrical and heating equipment, dish washers, etc., water control devices for x-ray and welding equipment and kindred products.

Clemens emphasized that Hays has been making a close study of the new and rapidly expanding potentialities of fiberglass reinforced plastics with a view to diversification of its products and in view of the fact that the use of plastics in the plumbing field has been growing increasingly.

"We decided to get away from a single field of operations," explained Clemens. "We wanted to diversify our business and feel that the fiberglass reinforced plastics field offered the greatest potentialities in view of its being so closely associated with the plumbing industry."

Plasticizer

The properties and uses of Dioctyl (Di-2-Ethylhexyl) Phthalate (DOP) as a primary plasticizer for vinyl resins are described in a Technical Service Bulletin issued and now available from Witco Chemical Company.

For copies of Technical Service Bulletin E-6, write to Witco Chemical Company, 260 Madison Avenue, New York 16, New York.

World of Color Provides Topic for South Texas S.P.E.

W. E. Wiese

Mr. H. B. Rockwood accompanied by Mr. H. A. Voskamp, Jr. of the Marketing Section of the Barrett Division of Allied Chemical & Dye Corporation discussed "Our World of Color" for the benefit of the South Texas Section in January.

The meeting was held in the Blue Room of the Alabama Banquet Building—Houston, Texas, at 7:30 P.M. January 20, 1954.

Mr. Rockwood used color slides and an interesting running commentary to illustrate the importance of color in the average person's every day life. Some excellent Kodachrome views of the Grand Canyon, Miami Beach, and other landscapes and pastoral scenes were demonstrated as a source of inspiration to designers and manufacturers, who are developing new colors for the consumer market.

In general, any new color falls into one of three classifications: forecast, decorator, or current. A forecast color is one that has been newly developed and has not yet been presented to the public. A decorator color is one which is being "test-marketed" through commercial decorators and interior designers in very limited fields. If a sufficient number of persons approve of a decorator color, it then becomes current and available through retailers for general consumer use.

An almost innumerable variety of colors are available in paints, pigments, fabrics, housewares, etc. Some sell successfully, while others become almost impossible to sell after the first three or four years. Others are successful as current colors over a fairly long period and can be reintroduced to the public from time to time. New colors are becoming available all the time because of new chemical combinations or because of new manufacturing techniques.

The House & Garden Magazine conducts a continuous survey of how well certain colors are being accepted by the public. Through the cooperation of hardware and paint stores, interior decorators and many other retail establishments, this information becomes available to interested manufacturers. House & Garden are able to report what colors currently are most popular, and they are able to predict what colors will be in demand next year.

At the end of the program both Mr. Rockwood and Mr. Voskamp answered many questions about the psychological, theoretical, and practical aspects of color as they affect the plastics industry.

Our speakers were introduced by Mr. L. C. Williams, Vice-President of the South Texas Section, who acted as Chairman of the meeting in the absence of Mr. R. W. Meyer, President.

The new officers of the South Texas Section for 1954 are:

Mr. R. W. Meyer, President; Mr. L. C. Williams, Vice-President; Mr. W. E. Wiese, Secretary & National Director; Mr. J. T. Pinkston, Treasurer.

Directors, including the above, are Messrs. L. D. Blackwell, F. Chalmers, L. B. Connelly, Harlan James, W. A. Meath, and Ky Sandow.

Plastics in Movies Described at Meeting Of Southern California

Walter H. Kadlec

Sixty members and guests attended the January meeting of the Southern California Section. Included in the business meeting was the presentation of a Sunbeam toaster to Robert Whann, retiring section president and director. Austin Herbst, in making the presentation, thanked Mr. Whann for his part in increasing the activities and membership during the past three years. Whann will represent the section as national director.

"The Use of Plastics and Allied Materials in Motion Picture Set Construction" was the subject of the technical program presented by Dr. Herbert Meyer and Mr. Dexter Huntington. Both speakers represented the Motion Picture Research Council which is an advisory unit to the industry on materials and methods.

Mr. Huntington used samples of almost every plastic type to show the use to which the materials are put. Thermoplastic sheeting can simulate armor plate while polyester-glass combinations can be used to realistically duplicate the battlements of a castle. Other resins such as vinyls can be slushed for reproduction of a museum piece and different forms of the same resin can be used as molds for massive jewels.

Dr. Meyer indicated that rising costs of set construction called for greater efforts in development of existing materials. He emphasized the search for new products to be tested by the council. The use of fresh foliage which requires almost daily replacement might be shifted to simulated plants in vinyls or elastomers. The problem of light values and translucency under the discriminating eye of the camera hinders an otherwise simple problem. Dr. Meyer stated that polyester films, thinner than those now in use, would give more footage per reel and would be more resistant to atmospheric changes. He pointed out that every new development in plastics became a candidate for the creation of effects and invited suppliers and processors to work closely with the picture industry.

Mr. Huntington attended the University of Chicago where he received his MS degree in Organic Chemistry in 1951. He joined the Council in 1952.

Dr. Meyer, a native of England, studied in Germany at the Institute of Technology, Berlin-Charlottenburg. His doctorate in organic chemistry was given in 1925. He was associated with Agfa abroad and in this country from 1926 to 1938. Dr. Meyer joined the council in 1948. He is a member of many of the societies in the motion picture field as well as the Society of Plastics Engineers.

The members of the Pacific Coast sections have been invited to attend the SPI conference to be held in Coronado next March 10, 11 and 12.

Mold Construction Panel Discusses Problems for Western New England

C. W. Petersen

On Wednesday, February 10, 100 members of the Western New England Section were treated to a series of authoritative talks on the subject of mold construction from three speakers, all experts in particular phases of this interesting field of plastics mold engineering.

Mr. Amelio Cocci of the Stan Cast Division, Standard Tool Company, Leominster, Mass., discussed beryllium copper molds while Mr. Walter E. Carlson of Carlson Pattern Company, Springfield, Mass., spoke about aluminum molds for molding reinforced polyester types and other materials.

Mr. William S. Dush of Parker Stamp Works, Inc., Hartford, Conn., rounded out the discussion with comments on conventional steel molds for compression and injection molding.

An informal type question session following the talks brought forth a general and enthusiastic participation by the membership. The subject of beryllium copper molds elicited a number of questions, particularly about the tolerances that can be maintained and the techniques of pressure casting beryllium copper.

The evening's display piece consisted of a mock-up of a typical beryllium copper mold construction along with samples of nylon, styrene and acrylic products produced from this type mold.

Use of Plastics in Business Machines and Film On Development of Orlon Presented at Philadelphia

H. C. Colby, Jr.

"The plastics industry is already a billion dollar business and yet still in its infancy," Mr. Frank Reynolds told the February 23rd Meeting of the Philadelphia Section of S.P.E. Mr. Reynolds is Manager of the Plastics Laboratory at the Endicott, New York, Engineering Laboratory of the International Business Machines Corporation. He spoke on plastics applications at IBM and the reasons for their use. It was most interesting to learn that they use at least seventeen different plastic materials in the manufacture of their various types of equipment.

Mr. Reynolds pointed out that the very nature of the electric and electronic accounting machines, time equipment and electric typewriters manufactured by IBM demands precision components. Plastic materials perform a very essential role in this and studies are constantly being made to utilize more of them wherever practical. A decision to employ a plastic part at IBM comes from one or more of the following functions: electrical insulation; machine improvement; cost reduction; or new machine development.

Mr. Reynolds stressed the fact that the responsibility for satisfactory plastic applications should be three-way between the material supplier, the molder, and the customer.

In the remainder of his talk Mr. Reynolds gave six case histories of IBM parts where plastics did a better job at lower cost. Major reductions in cost with improved performance came both from changing from other materials to plastics and from switching from one plastic to another more suited for the application.

The brush block is an example of progress from one plastic material to another with a third change contemplated. Originally this wire brush and connecting plug holder was machined and assembled from a thermoset laminate. A change was made to a more desirable laminate. Now IBM contemplates having this piece compression molded from a fibre glass alkyd which would give a major reduction in cost and improved performance.

The IBM control panel, a standard part on most of their accounting machines is another example of a change from a machined plastic to a molded one. Before the change to a compression molded part could be made dimensional tolerances had to be increased. Even so the precision required of the finished part was so great that special precautions had to be taken in the heat treatment of the steel to insure minimum change in dimensions and the mold specially designed to give accurate and uniform heating of the part during molding.

The pressure plate is currently being machined from an aluminum plate which is subsequently coated with an alkyd base insulating material. IBM is considering having this piece injection molded from a styrene copolymer. Despite the fact that it would be necessary to mold this piece in two parts to meet dimensional tolerances, major reduction in cost would result from shifting to the molded piece.

IBM is currently working to change the production of their stator moldings from a complicated combination of assembly, laminating, molding and further assembly and machining. If their experiments on injection molding nylon around inserts of the beryllium copper cores into sub-assemblies is successful, material savings in all of the operations of making this point will result.

The steel covers on many of IBM's accounting machines are painted with a gray wrinkle enamel finish to enhance their appearance. Because of the frequent maintenance required to retain an acceptable appearance, approval has been given to a vinyl-steel laminate for this application. Calendered and embossed plasticized vinyl sheet is laminated to flat sheets of steel. The sheets are then punched, drawn, and formed into covers. Although covers produced from this combination are more expensive, the great reduction in maintenance and superior quality justify the increased cost.

Mr. Reynolds' talk was followed by a color film furnished by DuPont on the development of Orlon. The progress of the development of this new fibre was vividly described from the search for a method to form this acrylonitrile resin into a fibre to the weaving of the finished cloth.

Did you get your salt water taffy in Toronto? There will be plenty of that and lots more at Atlantic City. Remember SPEAC—'55.

Southeastern Ohio Hears Talk on Kralastic

William J. Stranathan

Approximately 26 members and guests attended the February 18th meeting of the Southeastern Ohio Section of S.P.E. in Cambridge, Ohio to hear Herb Bendel of Naugatuck Chemical Div. of United States Rubber Co. talk on the relatively new material "Kralastic" which is one of those much discussed styrene copolymers. Mr. Bendel stated that Kralastic is a unique molding compound which will produce outstanding toughness and rigidity without sacrificing other desirable properties. This unusual strength has been secured by uniting the toughness of the elastomers such as synthetic rubbers with the rigidity of plastics into a stable compound.

As rubber plasticized condensation these resins are outstanding in their ability to be both hard and tough at the same time. In addition they are chemically resistant and have been used very much in the industrial field in the form of chemical containers such as vats, ducts, pipes, etc. Small items such as cams, gears, etc. have proven their superiority over wood and metal.

Mr. Bendel concluded his talk with a question and answer period on the subject.

A business meeting and dinner preceded the talk by Mr. Bendel. The meeting was in charge of John Chomicz of General Electric Co., Coshocton, Ohio.

Interesting reports were given by four members on their visit to the National Technical Conference in Toronto.

It was announced that Ken Mallet has joined our ranks as a new member. Ken is from Shellmar-Betner Div. of Continental Can Co. Zanesville, Ohio. We hope that Ken can be as faithful a member as all the others from Shellmar. Let's keep new members headed our way in '54.

Central Ohio Meet On Properties of Rigid PVC

R. W. King

The February meeting of the Central Ohio Section was held at the Beechwold Restaurant in Columbus, Ohio, on the 17th. The speaker for the evening was Mr. Harry Zimmerman of the B. F. Goodrich Chemical Co. He is their new District Sales Representative for this area, having taken over the duties of Jim Detwiler who recently accepted the position of Assistant General Manager of the Yardley Plastics Co. in Columbus.

Mr. Zimmerman presented a talk on the "Processing, Properties and Applications of Rigid PVC." This material was first used commercially in Europe where it found wide application because of its corrosion resistance. It was introduced into the United States shortly after World War II and has enjoyed a rapid growth. Mr. Zimmerman's talk was illustrated with slides and articles that had been fabricated from rigid PVC. The latter pointed out the versatility of this material since they included injection and compression molded articles, extruded sections, calendered sheeting and articles fabricated by the use of hot-gas welding techniques. The talk also included a discussion of proper mold and die design so that optimum properties could be obtained.

Milwaukee Is Host To Oelman and Healey

Marion C. Stowe

On January 19, 1954, the new Milwaukee section of Society of Plastic Engineers held its second meeting having an attendance of 60 persons. This attendance can be compared with the first meeting when 19 men attended. The future of the new section is very promising.

We were honored with the presence of Mr. Walter Oelman, President of the society and Mr. Joseph Healey, National Membership Chairman. Mr. Oelman gave an enlightening talk on the goals and progress of the S.P.E. and Mr. Healey was very impressive with his talk on the promoting of Plastics within and outside of the society. Mr. Oelman mentioned the society being 11 years in existence with present membership of 3000. There are three or four new sections coming into the society in the not too distant future.

Mr. George Stein, Acting Chairman of the Milwaukee section invited the society to have its National Convention in Milwaukee on its first open date.

This year the Milwaukee section will be represented at the National Convention being held in Toronto, Canada on January 27, 28, 29, by Mr. Frank Bailey, Secretary of the Milwaukee section. Mr. Bailey will be presented with the charter for the new Milwaukee section thus being established as the 28th section of the society.

PLASTICS AROUND THE WORLD

(continued from page 34)

centration, unequal or compound stresses should be avoided wherever possible. Deep threads should be avoided in piping, and for large diameters joining is best done by welded flanges. A number of detailed examples are presented for the use of PVCl in chemical plants handling corrosive acids. The use of rigid vinyl for tank lining requires particular attention to the differential expansion coefficients between metal and plastic. Loose inserts, plastic-ization, or soft backing may be employed to overcome these stresses.

CONTROL EQUIPMENT DEVICES FOR COMPRESSION AND INJECTION MOLDING, pp. 46-62. By G. T. Collins

Automatic controls for compression molding are recommended as a means of obtaining uniformly good results. The paper deals primarily with combined electrical and mechanical controls for the timing cycle. The types and operation of control equipment for both compression and injection molding processes are discussed in detail. The control circuits are described by means of graphical symbols and their operations are followed thru in their proper sequences. Control systems for compression molding include the following steps:

1. Push button operates relay.
2. Relay starts timer and operates solenoid closing motor and guard switches.
3. First main ram cam controls low pressure press closing.
4. A second cam controls high pressure and transfer circuits.
5. Breather cams open and close main ram circuit for required time.
6. The cure circuit can be variably adjusted.
7. Tripping cams open main ram and high pressure circuits.
8. Ejection circuit is final control, resetting relay and process timer for next cycle.

Adequate safeguard permitting complete automatic continuous cycle operation has not as yet fully developed, but appears as a near future ultimate goal.

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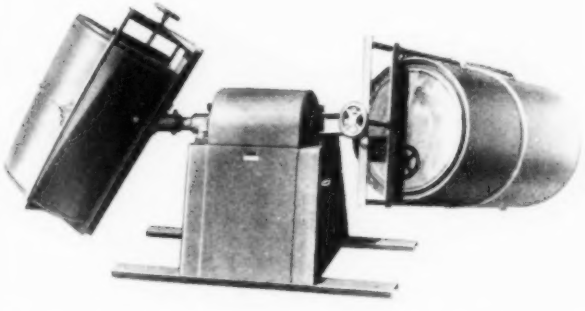

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Radiation Changes

(continued from page 111)

The carbon dioxide present is probably from the organic acid used to catalyze the polymerization of the polymer.

This and the second sample were irradiated in an atmosphere of nitrogen and since different weights of the materials were used only the ratios of the gases other than nitrogen are significant.

The gas analysis of the polymer with a mol ratio of greater than 0.01 to 1 of carboxyl to methylene gave the following gas analysis:

CO	39.4 mol %
CH_4	0.6 mol %
H_2O	0.9 mol %
H_2	40.3 mol %
N_2	18.0 mol %

These analyses show that approximately one hundred carboxyl groups decomposed for one methylene group in the polymer with a 0.1 to 1 mol ratio of carboxyl to methylene. In the other polymer over 200 methylene groups decomposed for each phenyl group present. One feasible explanation is the assumption of functionality series as postulated.

FURTHER EVIDENCE FOR SERIES

Further evidence for this series was received in a recent communication with Dr. A. Charlesby of Harwell, England who showed that upon exposure of Teflon that the predominating gaseous decomposition product was carbon tetrafluoride with lesser quantities of fluoride ions. This in turn indicates that the CF_2 units will transfer the excess energy to the end of the chain where selective decomposition will occur. Infra-red studies[9] conducted on Teflon by our own laboratory indicated the formation of $-CF_2-CF_2-$ and $-CF_2-CF$ units when irradiated. The latter group could easily be formed from the following type of reaction:

$$\left(\begin{matrix}F\\C\\F\end{matrix}\right)_n - \begin{matrix}F&F&F\\C&C&CF\\F&F&F\end{matrix} \xrightarrow{h\nu} \left(\begin{matrix}F\\C\\F\end{matrix}\right)_n - \begin{matrix}F\\C\\F\end{matrix} = \begin{matrix}F\\CF\end{matrix} + CF_4\uparrow$$

Assuming the validity of this hypothesis the changes in mechanical properties of Teflon, polyethylene, polystyrene, and certain polyesters which occur upon irradiation can be explained.

Teflon is unique in this group, because upon exposure, the reactions are such that crosslink formation is seriously hindered. The polymer, when exposed to gamma radiation is restricted to the evolution of fluoride ions and organic fluorides accompanied by double bond formation in the chain. The double bonded C-F units have a smaller atomic distance than the usual two CF units. The formation of these units in quantities as low as 0.01% causes serious embrittlement effects due to the strains produced. X-ray diffraction studies of this material have shown a decrease in the intensity of the bond which represents the repeat distance of the unit cell with increasing exposure. Permanganate oxidations show positive evidence for the formation of double bonds. This material upon exposure of one to two minutes of high intensity radiation crumbles and its mechanical properties show deleterious effects very quickly.

POLYETHYLENE CROSS-LINKS

Polyethylene[10] on the other hand is the hydrogen analog of Teflon but is quite capable of cross linking when irradiated.[1] The X-ray diffraction measurements indicated major changes in structure, much more than in Teflon, but the formation of cross linkages preserves the mechanical properties at low dosages. After long time exposure the cross link formation overshadows the other reactions as indicated by a decrease in the elongation and increase in elastic modulus.

The relative stability of polystyrene[4, 5, 6] has been investigated. However, there is no direct evidence which shows what products occur upon exposure to radiation. The stability of this material has been attributed to the radiation resistance of the phenyl groups. This "resistance" implies that the phenyl group does not interact with photons. This is analagous to the situation where rain is falling harmlessly on a barn. To say that the barn does not react to the rain and therefore is rain resistant is ludicrous. A more proper explanation of the stability would be to say that the barn is structurally capable of absorbing the energy from the rain and can dissipate it without evidence of reaction. So it is that we postulate the ability of the phenyl groups to absorb radiation energy and transfer it to other groups where it is dissipated. Unfortunately there are not enough data available to determine the deterioration mechanism. From the changes in the mechanical properties and polymers which have been observed, it is evident that cross linking is one of the major reactions which occur. This is evident from the increase in elastic modulus and decrease in energy to break which occurs with increasing exposure.

POLYESTERS POTENTIALLY OF INTEREST

Linear polyesters represent a potentially interesting set of materials because of the predominance of ester carboxyl groups and the relatively short distances between them. It may be possible to change the characteristics of these materials with exposures which would produce quantities of low molecular weight products which would tend to act as internal lubricants. It is interesting to note that the compounds which have had their elastic characteristics most significantly changed are ester compounds. Sisman realized an increase in elongation to break of an ester compound from twenty to over three hundred percent by a short time exposure. This was accompanied by a slight decrease in elastic modulus.

In these materials the rate of application may have appreciable effect on the results, as shown by the work of Burr and Garrison[3].

In conclusion, it is evident from recent and past work in this field that we can anticipate an increase in the high temperature characteristics of polymers as well as the production of materials with a greater variation in properties than heretofore possible. Radiation effects present a field that deserves extensive exploration.

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Why More Plastics?

(continued from page 23)

U.K. An electron bombardment, however, does not penetrate so deeply and the effects are more on the surface.

Many of the new techniques do not give new polymers but simplify the methods for preparing old ones. Such a technique is the "Alfin" method for polymerising some unsaturated hydrocarbons, for example butadiene. It may be that by using this type of catalyst which containing amongst other ingredients sodium propoxide and sodium chloride, crude butadiene can be polymerized without an expensive purification step.

Other systems of polymerization have been suggested, for example polymerization in the gaseous phase and polymerization in such a way that layers of different polymers can be built up one above the other. Perhaps something commercially important will come of these developments, but again the chance of getting materials vastly different in properties from the polymers we already know, seems small.

Progress in plastics or in any other industry is the result of two pressures, one from within the industry and the other from outside. Largely from outside the industry comes the pressure to replace metal. For years most of us have derided the journalistic reports, according to which the Bronze Age and the Iron Age would be succeeded by the Plastics Age. Many of us in the U.K. have suggested that the Aspirin Age would be just as likely. The journalists, however, have proved to be right, for today plastics are being used more and more to replace metals. The polyester-fiberglass laminated car body is not yet perhaps big tonnage business, but in less spectacular industries plastics are steadily encroaching on metals. Thousands of tons of polythene and rigid P.V.C. have, for example, gone into pipe lines for the transport of liquids frequently corrosive. In the U.K., for example, one pipe 36" in diameter and weighing 25 tons has recently been laid to convey sulphuric acid effluent.

There is now a welcome tendency to make plastics available in profiles familiar to engineers. This is true not only of relatively cheap plastics such as rigid P.V.C. and polymethyl methacrylate but also of expensive materials such as nylon and polytetrafluoroethylene. A fall in the price relative to other engineering materials and an increased awareness of the possibilities of these new plastics will greatly speed up the rate of development.

It would perhaps be wrong to say that there is a present demand for new polymers and modifications to old ones from the textile industry. Here the pressure comes from polymer chemists and physicists, many of whom are keen to repeat the success of Carothers. Strangely enough, Carothers was not the first man to make a wholly synthetic fibre. The credit goes to Germany where in 1913 polyvinyl chloride fibres were made by Griesheim-Elektron. Carothers has, of course, many other claims to fame, not least the production of the first melt spun fibre. The names of the polymers which have caused such a stir in the textile industry in the last 20 years are well known to all of us, nylon, polyethylene glycol-terephthalate, polyacrylonitrile, polyurethane and vinyl chloride polymers and copolymers. What of the others which are being tried in the laboratories all over the world? One which appeals because of its simplicity is polyvinyl formal made by stretching polyvinyl alcohol and reacting it with formaldehyde. It seems possible that this fibre will go into production commercially in Japan where much work was done during the war. Polyvinyl alcohol is one of the most readily crystallized polymers in which respect it is completely different from its parent polyvinyl acetate which cannot be induced to crystallize at all. As far as is known, most of the new fibre-forming polymers are, like nylon and "terylene," condensation polymers and not vinyl polymers like polyacrylonitrile. Apart from the various polyesters and polyamides, aromatic and aliphatic, the new materials seem to be polyanhydrides, polypeptides, polyureas and triazoles.

There are no signs of any cheap wholly synthetic textile fibres and all of them, new and old, are likely to be in the wool and silk price range and not in that of cotton, which is out on its own as a cheap, useful fibre.

The use of plastics is becoming so widespread that it is not surprising that many new industries could hardly

(please turn to page 42)

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Why More Plastics?

(continued from page 41)

exist without them. Aircraft, for example, depend on plastics for many components ranging from flexible fuel tanks to windows. The windows we all know about because we have looked through them so often, and they give an example of the demands which a rapidly growing industry is making on plastics. For about 12 years polymethyl methacrylate sheet has been adequate for aircraft glazing. The aircraft of the supersonic age will, however, need a transparent plastic with a high softening point to withstand the ram compression heating, particularly at low altitudes in the tropics. The problem is not solved, and at present the only alternative to polymethyl methacrylate would seem to be glass with all its defects of weight and fragility. Lightly crosslinked polymethyl methacrylates are slightly better than the ordinary varieties and polymethyl chloracrylate is better still, but it is doubtful if these materials would meet the ever increasing demands of the aircraft industry for more than a few years.

If, then, there are not likely to be any radically new plastics made in any large tonnages in the near future, where is progress likely to be? Some of the lines of development have already been indicated. The most obvious of all is the finding of new applications. It is one of the truisms of the plastics industry that the original application for a new plastic is usually less important than those applications which come out of the blue after a few years. Polymethyl methacrylate in the U.K. is a good example. The first plant was erected for the manufacture of knife handles, an application for which the tonnage sold today is insignificant. Polythene is another good example. For many years, largely due to the war, the only application was for high frequency cables. Ultimately, perhaps not more than 20% of the polythene produced in the world will so be used. Butadiene copolymers have, perhaps, proved as versatile as any. They started life, with butadiene as the main constituent, for tires. Today, with the proportions of the ingredients almost reversed, the copolymers are being used for applications as diverse as leather substitutes and water paints.

Many of the new and important applications are technically ingenious rather than chemically interesting. Nylon monofil for pan scrubbers, quite a large tonnage development, falls into this category.

Another important avenue of progress is in improvement of fabricating techniques. Quite a lot has been done and we now have better calenders, better presses and better extruders, but the cost of production in the plastics industry is high compared to that in the metal industry. For example, consider the cost of fabricating sheets from P.V.C. and from metal. Stainless steel on a volume basis is 6.5 times as costly as P.V.C. polymer, yet stainless steel sheet is only 2.7 times as expensive as P.V.C. sheet on a volume basis, in spite of the fact that stainless steel is notoriously difficult to process. Similarly, aluminium ingots are 1.5 times as costly as P.V.C. polymer, yet the cost of aluminium sheet is about 60% of that of P.V.C. sheet[2]. There are, of course, good reasons for these differences, amongst them inadequate background knowledge, variable raw materials and low outputs, but if the industry is to grow at the expected rate, much fundamental work will have to be done on improved methods of fabrication. Discoveries in one field of polymers will, of course, affect developments in another, for example, progress in the extrusion of fibres will assist progress in the extrusion of sheet and films.

The title of this paper is "Why More Plastics?" To some extent the title was an excuse to give one view of where the industry is and where it is likely to go. I think the answer to the question is implicit in what I have said. New industries are demanding new materials. Where the radically new plastics are coming from no one knows and it may be they will never come. If they do not, there is quite enough to do, for our lifetime at least, in exploring the paths opened by Staudinger and Carothers.

At the beginning of the talk I put forward some subsidiary questions. Let us see if answers are now possible.

Can we do much more with present plastics? Clearly we can do a great deal more. It is desirable to have more plastics? Highly desirable. Is it possible to make more plastics? Yes, but our present knowledge suggests that their properties will not be vastly different from those of the plastics we already know. Can more plastics be justified on economic grounds? In special cases, yes, but high prices are likely to limit development unless the properties are outstanding. An everlasting fibre or synthetic rubber would obviously command very high prices.

Plastics, in other words, are coming of age. Nobody expects a new metal every year and when one comes along it hits the headlines, as titanium is doing now. And yet the metal industries go on from strength to strength with minor technical advances in alloys and techniques.

Perhaps I have been rather pessimistic. If so, I sincerely hope I am wrong.

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Crazing of Polystyrene

(continued from page 21)

"masking" tapes have been found in actual use on cast polystyrene sheets which lowered the critical stress level to 500 psi! A change in adhesive formulation eliminated the crazing difficulties which had been encountered in these particular cases.

H. Size and Visibility of Crazing Cracks

Photographic enlargements were made from electron microscopic pictures of crazed areas of polystyrene mouldings. In the gross magnification of 26,000 X it was possible to see craze cracks of definite width and in fact to measure and compute their width as approximately 0.000002 inches (two millionths of an inch). This dimension refers to cracks which, although definitely visible to the unaided eye, are nevertheless of the smaller variety characteristic of initial crazing. Much larger cracks associated with advanced crazing may be several thousandths of an inch wide.

Crazing cracks may be very easily seen in crystal clear or lightly colored translucent moldings by virtue of the light reflected off the craze planes to give a somewhat exaggerated impression of a multitude of internal fissures. Reflections from a brilliant light source are most existent in opaque moldings where internal crazing cracks cannot be seen but where surface crazing can under proper circumstances. It has been found that even the small cracks described above may be shown up in most opaque moldings by the use of a red or green "paint" (chosen so as to contrast with the original color). Blood red may be made up by mixing ferric thiocyanate in alcohol; green by mixing Malachite Green in alcohol. Either one, if rubbed in all directions on the surface of a molding with a soft cloth and then removed as completely as possible

rubbing with clean cloths, will make crazing stand out clearly on the surface of opaque

1. **Use of Immersion Reagents**

It is obvious from the work which has been presented that these developments in the crazing of polystyrene may be put to very practical use in a variety of ways. An attempt has already been made to point out in some detail the reasons why many commonly used articles molded from polystyrene have not always performed satisfactorily in extended use. In this connection we have tried to emphasize the importance of (1) careful choice of raw material, (2) thoughtful design of the plastic article as well as the mold and auxiliary equipment for making it, and (3) quality workmanship. The desired result was a choice of material with the highest critical elongation in contact **with reagents encountered in actual service,** together with a reduction to a practical minimum of internal stresses (in some cases attained by annealing).

A related but totally different use of the same fundamental information involves immersion of molded articles in liquid reagents for the determination of internal stress levels. Thus by the choice of **proper reagents,** followed by immersion at **controlled temperature** for an **adequate time period,** the invisible but highly important internal stresses in polystyrene moldings may be determined. The information contained in Table VIII, while far from complete, indicates what may be done in cataloging the effect of reagents on polystyrene in descending order of critical elongation or critical stress.

Warning should be given that use of the information outlined in Table VIII is not as simple or foolproof as it might appear. Considerable study of the problem should be made first, the fundamentals of polystyrene's crazing behavior should be understood, and the effect of contributing variables should be appreciated. The following points should be considered before undertaking actual test work.

1. Acceptable internal stress level should be decided upon ahead of time, preferably on the basis of **actual use tests.**
2. Moldings must not be tested while still warm, i.e. directly out of the molding machine. They must be allowed to reach equilibrium before they are immersed in test reagents held at constant temperature.
3. Time of immersion necessarily varies with **type of stress** involved as well as **thickness of the parts** to be tested. The values listed in Table VIII are **minimum values** and in some moldings it may take 30 minutes or more for even a fast acting reagent to penetrate the innermost portions of a heavy section where tensile stress may be the greatest. Remember that if more crazing occurs with additional immersion time, the plastic part has not reached equilibrium and a final decision on exact stress level cannot be made.
4. Parts immersed in test reagents are permanently damaged and should be destroyed. The same part cannot be used for immersion in more than one type and strength of solution.
5. Remember that no two moldings were ever made **exactly** alike as far as internal stresses are concerned. In setting up test procedures, use the "average" of several trials.

IV. SUMMARY —

New testing equipment has been developed and techniques have been perfected which make it possible to study the crazing of polystyrene and to develop information of fundamental importance in product design and in predicting field service life.

Critical elongation values of polystyrene have been determined in contact with a wide variety of reagents under conditions of carefully controlled but widely varied times, temperatures, degrees of orientation and internal stresses.

As a result of the work completed to date, some conclusions of theoretical value have been drawn. Of more importance from a practical standpoint, much information is now available which should prove very useful to designers, molders and fabricators of polystyrene parts. Correlation of these laboratory tests with field experience

(please turn to page 46)

Table VIII
Test Reagents
(Effect on Polystyrene at 75° F.)

Reagent	Minimum Equilibrium Critical Elongation, %	Minimum Equilibrium Critical Stress, psi.	Effective Speed
Air or water	0.33	1500	very slow
Isopropyl alcohol	0.28	1250	fast
Methanol or ethyl alcohol	0.23	1000	fast
Lactic acid	0.20	900	very slow
10% Normal heptane, 90% isopropyl alcohol	0.18	800	fast
15% Normal heptane, 85% isopropyl alcohol	0.16	700	fast
20% Normal heptane, 80% isopropyl alcohol	0.13	600	fast
25% Normal heptane, 75% isopropyl alcohol	0.11+	500	fast
30% Normal heptane, 70% isopropyl alcohol	0.10	450	fast
40% Normal heptane, 60% isopropyl alcohol	0.07+	350	fast
50% Normal heptane, 50% isopropyl alcohol	0.06	300	fast
60% Normal heptane, 40% isopropyl alcohol	0.05	250	fast
70% Normal heptane, 30% isopropyl alcohol	0.04	200	fast
85% Normal heptane, 15% isopropyl alcohol	0.03	150	fast
95% Normal heptane, 5% isopropyl alcohol	0.02	100	fast
Normal heptane	0.01+	50	fast
Petroleum ether	0.01−	<50	fast

Polyester Resins

(continued from page 29)

number of peroxides and hydroperoxides—alkyl peroxides, ketone peroxides, acyl peroxides and mixed peroxides. In general each of these peroxides is most effective at a specific temperature. Some peroxides, such as organic carbonate peroxides and certain ketone peroxides (DDM, FDM) are effective at relatively low temperatures, i.e. 40-50 C. Benzoyl peroxide is effective at 70 to 90 C, while still others such as chlorobenzoyl peroxide and acetone peroxide are effective at temperatures as high at 140 to 150 C. It is interesting to note that in general the optimum curing temperature with each of these peroxides corresponds fairly closely with the thermal decomposition

Mr. Savage, who presented this paper at the 10th SPE Conference in Toronto, demonstrates the making of a boat with the help of a model.

point of the peroxide, and suggests that the effective catalyst is an unstable decomposition intermediate of the peroxide (free radical or a univalent oxygen group).

Characteristic of these resins, and of major importance, is the fact that pressure is not required to effect cure nor are volatile by-products produced during cure. These facts promptly enlarge the scope of application of these plastic products, and permit the production of large contoured shapes without the need for expensive presses and with simpler tooling than has hithertofore been possible. Until recently it was necessary to heat the peroxide catalyzed resin at a temperature of approximately 100 to 125 C in order to obtain cure within a reasonable period of time. However, more recently room-temperature accelerators have been developed which permit these resins to cure at room temperature without the application of any external heat. This has eliminated the need of heating equipment, heated molds, and autoclaves. It also permits the use of non-heat conductive materials such as reinforced polyester, plaster, wood or concrete, and thus materially simplifies the processes of molding and reduces cost. These resins have also been characterized by the fact that the cure of the resin was inhibited by air, and therefore surfaces exposed to air were tacky. Within the past several years, this limitation of the polyesters has been overcome and polyester resins are now available which cure tack-free at room temperature. The importance of this for the coating and paint field is obvious.

Model is definitely impressed as Mr. Savage lifts out the completed boat at the end of his talk.

More recently a thixotropic polyester has been developed, which may be handled like the ordinary liquid resin, but will not drain or run when applied even to smooth vertical surfaces. The viscosity of this resin is a function of the shearing force applied; and so, it can be easily brushed, sprayed or spread by squeegee on reinforcing materials or mold surfaces. Its ability to stay put, however, overcomes the major problems encountered in producing molded laminates by hand lay-up procedures.

Preimpregnating polyesters have now also been made available. These resins may be used to saturate reinforcing materials, such as glass cloth, and dried to a tack-free or only slightly tacky condition. The saturated reinforcing material may then be stored at room temperature for periods ranging up to several months and used as needed. In this way resin impregnation can be accomplished efficiently in one continuous operation and fabricators then work with a comparatively dry, more easily handled material.

POLYESTER APPLICATIONS

Polyesters have found general applications in the following important fields:

1. **Casting:** Casting of these resins in simple molds and at room temperature has made possible the production of a great many items which heretofore have been made from cast phenolics and from injection and compression molded thermoplastic and thermohardened resins. Knife handles, rods, beads, brush backs, clock cases are examples of the type of product which have been made in lead molds typical of the cast phenolic industry. In addition a great many carved intricately shaped objects with undercuts have been made in flexible molds. Such items are boxes for candy, perfumes, cigarettes and ash trys, book-ends, figurines and the like. They are now being produced in large quantities in a variety of colors and shapes; requiring a minimum of invested capital.

2. **Laminating:** These resins have been used for the continuous production of laminates and were widely used during the last war for the production of liners for fuel tanks for aircraft in many millions of square feet, using glass cloth as the reinforcing medium. Since the war they have been used for the production of table top material, corrugated sheeting for roofing, partitions and sky-lights, wall coverings and the like.

These resins have been used very satisfactorily by a patented method for the production of large items such as boats, caskets and various motor and other housings. Boats for the United States Navy 28 feet and 36 feet in length have been made successfully. They show many advantages in terms of greater strength, lower weight, lower cost, and greater serviceability, and do not require painting or maintenance of any type.

method employed makes use of low-cost mating which the reinforcing material is laid up dry. is introduced between the molds by vacuum, a combination of the two. In this way, a fully laminate of highest quality is efficiently finishing is kept to a minimum, air entrapment and workmen need not come in direct contact the resin.

advantages of strength and rigidity combined weight gained through the use of a "sandwich" having a "honeycomb" core has been long rec- This type of production has now become feasible use of thixotropic polyesters which permit layup operation since the resin will not drain into the The thixotropic resins have also proved ideal applications of pigmented or clear gel coats to sur- of molds used for producing laminates and for adhesive applications where no volatiles are de- and the resin used must stay in place without drain-

3. **Adhesives:** These resins have shown promise as but this application is rather limited at the present time.

4. **Impregnation:** One of the important applications of new resins is their use for impregnating plaster and in order to obtain stronger, tougher, harder and weather-resistant materials. This application is be- to take on a greater importance with the develop- of non-air inhibited resins.

5. **Electrical:** Perhaps one of the most important ap- for these resins is in the electrical field. They now very widely used for impregnating and for en- capacitors to replace the tubular types formerly The production of such capacitors has now reached figures. The encasing of electrical coils, trans- and the like, is now being successfully developed. should be remembered that these resins have particu- good electrical properties having a dielectric con- of 2.8 to 3.4 and a loss factor of approx. 0.35%. They show excellent properties for radar applications, and now used almost exclusively for the production of in the U.S.

6. **Compression Molding:** These resins may be formu- in a heavy putty like material with and without glass which can be extruded and cut to size and used for pression molding. They have many advantages over phenolic molding materials, since they can be cured relatively low pressure in thin sections in a matter of to 40 seconds and in heavier sections in as little as 2 minutes. They are particularly good for electrical because of their high arc resistance.

7. **Embedding:** These resins are very useful for em- metal sections for micro work, flowers, insects, gical specimens and the like and are finding many in this field.

8. **Photoelasticity:** Some of these resins show par- good photoelastic properties and are being used such purposes in stress analysis.

9. **Coating compositions:** The development of a room curing, non-air inhibited polyester resin has possible the production for the first time of a truly paint. This development is still in its early stages, it is indicated that there is considerable promise in this Already there is a large application in the petroleum for the painting of pipelines and petroleum storage and also for painting porous construction materials

(please turn to page 46)

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Crazing of Polystyrene

(continued from page 43)

has been excellent, leading to the belief that, in the long run, the availability of higher quality plastic moldings on the market should result in both wider use and greater consumer satisfaction.

Acknowledgement

Considerable assistance was given the author in the preparation of this paper by many individuals in several different laboratories within The Dow Chemical Company. Two men, in contributing work of outstanding significance, deserve special recognition. They are R. B. Clarke and R. W. Miler, both of Plastics Technical Service.

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(2) Residual Strains in Injection Molded Polystyrene. R. S. Spencer and G. D. Gilmore, The Dow Chemical Company, November, 1950.

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(12) Stress Cracking of Polyethylene. R. H. Carey, ASTM Bulletin, July, 1950.

Polyester Resins

(continued from page 45)

such as concrete, plaster and wood surfaces. A substantial volume of business is already being done in surfacing cinder building blocks with pigmented resin. One or both solid sides of the block are coated prior to installation so when the blocks are set in place either the interior or exterior surfaces or both are attractive in appearance, sealed against moisture and require no painting or further treatment. These resins, being free of volatile solvents yet extremely low in viscosity, penetrate into the porous material and then cure to give rise to the final product in which there is no film to dry and be scraped off or subject to normal paint failures. The coating field represents the most recent development of this new series of resins.

ACS Symposium on Structural Plastics

A symposium on "Plastics as Materials of Construction" will be conducted by the Division of Industrial and Engineering Chemistry of the American Chemical Society during the meeting of the Society in New York City, September 12-16, 1954. The committee planning the program for this symposium includes Howard K. Nason, Director of Research of the Organic Chemicals Div., Monsanto Chemical Co., St. Louis; Dr. Gordon M. Kline, Chief of Organic Section, National Bureau of Standards; and Dr. A. G. H. Dietz, Professor of Building Engineering and Director of the M.C.A. Project at Massachusetts Institute of Technology. Drs. Kline and Dietz are members of SPE. Two sessions are planned, one on reinforced plastics, the other on plastics used without reinforcement. There will be six or eight papers per session.

A.S.T.E. Plastics Program at Philadelphia

Plastics engineers in and around Philadelphia will be interested in part of the program being presented at the annual meeting of the American Society of Tool Engineers being held in Philadelphia April 26 through 30, at the Bellvue-Stratford. Three papers will be presented starting at 9 a.m. on Friday, April 30; Plastic Fixtures Have Wide Use, by B. Sokol; Plastic Dies Move Into Regular Production Service, by G. C. Adams; and Plastic Auto Body Developments, by W. A. Hermonat.

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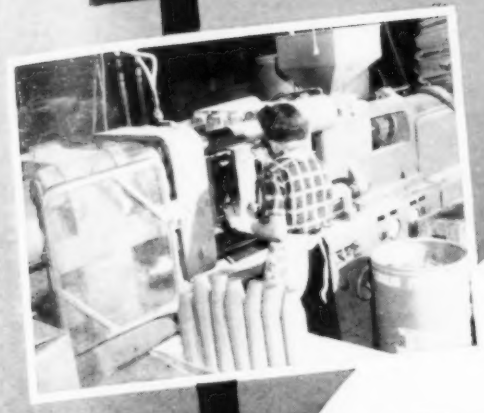

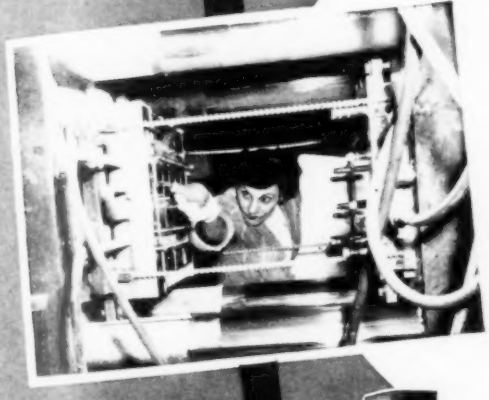

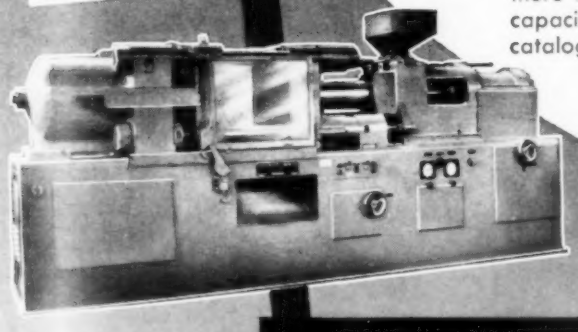

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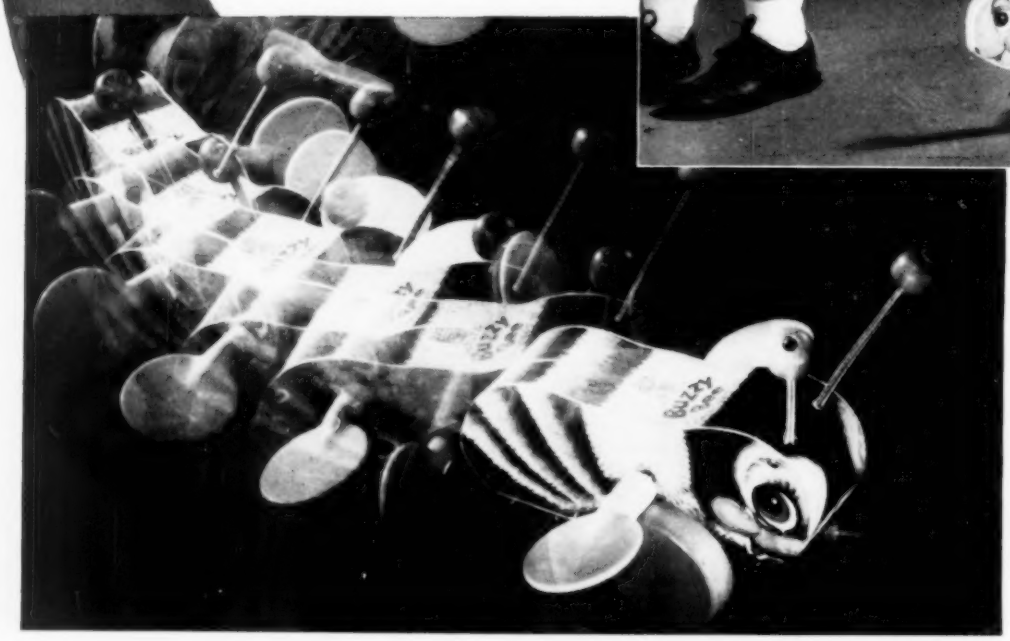

On the move with Hercocel are many new Fisher-Price toys. A clever combination of painted wood and tough plastic, Timmy Turtle (*above*) has an unbreakable Hercocel shell; Buzzy Bee (*left*), Hercocel wings. Other toys in background use Hercocel parts for added color and play interest.

Toys manufactured by Fisher-Price Toys, Inc., East Aurora, New York. Hercocel parts molded by Tenrold, Inc., Kenmore, New York.

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